Ecology of Cowles Fringe-toed Lizard

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Executive summary

Rainfall patterns during this study provided sharply contrasting conditions, as 1995 had a wet winter/spring and dry summer while 1996 had a dry winter/spring and relatively wet summer.

We found *Uma notata* to be abundant in the Mohawk Dunes, with population densities in good habitat of 15-17/ha. Their springtime physical condition, as indicated by mass/length regressions, varied according to weather conditions, with lizards measuring significantly fatter in 1995 than in 1996.

Their physical condition appears to have affected reproduction. Male reproductive readiness, as shown by testis volumes, peaked in April and May. It declined to relatively low levels by August, though that decline was less pronounced in 1996, perhaps as a result of the summer rains in July and August. Female egg production peaked in May during 1995 but did not occur in spring 1996. Limited egg production in August-September 1996 suggests the possibility of two reproductive seasons during years with both winter and summer rainfall. The 1995 hatchling cohort emerged during June-October, but we detected no 1996 cohort.

Survival rate estimates were high in both 1995 (0.818) and 1996 (0.923).

Thermal measurements at the time of *Uma notata* observations showed a mean surface temperature of 40.0°C. Mean body temperature of captured *Uma* was 37.9°.

Minimum convex polygon estimates of home ranges were 530 m² for adult males and 228 m² for adult females. When adjusted for a sample size bias, these estimates were 994 and 1446 m², respectively. We observed little overlap between adult home ranges.

Overall, 45% of *Uma notata* we examined had evidence of tail loss, suggesting relatively high levels of attempted predation.

Uma notata actively used perennial plants as escape cover, preferentially selecting *Ambrosia dumosa* while using *Ephedra trifurca* and *Hilaria rigida* less than they were available.

We also found significant use of plant materials in *Uma notata* diet, comprising 49% of total diet volume and 23% of total prey items. Young lizards ate primarily insects, adding progressively greater proportions of plant items with increasing body size, especially among males. For most size classes there were seasonal shifts, with progressively smaller proportions of plant material as the warm season progressed. Overall, their diet included 65 taxa of arthropods from 39 families, along with 13 plant species in 7 families.

Acknowledgments

Introduction

The Colorado Desert fringe-toed lizard, *Uma notata* (Reptilia: Phrynosomatidae) is a species endemic to wind-blown sand dunes of North America, occurring in southeastern California, southwestern Arizona, northeastern Baja California Norte, and northwestern Sonora (Norris 1958, Pough 1977). It has suffered severe declines in some populations due to off-road-vehicle use, correlated with loss of vegetative cover. Reasons offered for these declines include loss of escape cover and loss of arthropod food resources associated with the vegetation (Luckenbach and Bury 1983, Maes 1990).

Because of their obligate association with wind-blown sand dunes, most *Uma* populations can be considered as island populations, with most of those islands ranging from 2 to 2,500 ha (though the few larger occupied dune fields include the "continental" 233,000-ha Gran Desierto) (Norris 1958). Their habitat is characterized by high temperatures, low rainfall, low primary productivity, and an absence of free water (Turner and Brown 1982, Bowers 1984).

Some authors have considered *Uma notata* one of three closely related congeneric species in the U.S., the others being *U. inornata* and *U. scoparia* (Heifetz 1941, Mayhew 1964b), though the group has also been variously lumped as two (Norris 1958) or one (Adest 1977, Zalusky et al. 1980) species. For this discussion, the first case will be assumed.

Two additional species of *Uma* - *U. exsul* and *U. paraphygas* - occur far to the east in the Chihuahuan Desert in Mexico. While they share the same suite of adaptations to loose sand environments, they are much more distantly related to *U. notata* than its U.S. congeners (Adest 1977, Zalusky et al. 1980).

Cowles's (sic) fringe-toed lizard, *Uma notata rufopunctata*, was first described as such by Norris (1958). The type specimen, collected at Monument 200 in the Yuma Desert, Arizona (Pough 1977), was originally described as *Uma rufopunctata* by Cope (1895). Heifetz (1941) described an additional subspecies, *Uma notata cowlesi*, from coastal Sonora, Mexico. Norris (1958) combined these to cover all populations in Sonora and Arizona.

Despite being locally abundant, relatively visible diurnal animals, the fringe-toed lizards are a poorly understood group. Most research that has been done on the genus *Uma* has focused on the federally protected *Uma inornata*. Very little is currently known about the species *Uma notata*, and essentially all of that research was conducted in California on the subspecies *U. n. notata*. Genetic differences between the subspecies, along with biological and climatic differences in their habitat, suggested that useful knowledge may be gained from studies in Arizona. Cowles fringe-toed lizard (*U. n. rufopunctata*) is a taxon of very limited distribution in Arizona, being almost entirely restricted to the Pinta Sands, Yuma and Mohawk sand dune systems. As such, it may be strongly affected by any future habitat loss or modification.

This study was designed to complement a pre-existing project funded by the Department of Defense Legacy program to inventory, develop monitoring protocols for, and establish baseline monitoring data on sensitive herpetofauna of the Mohawk Dunes (Turner et al. 1997a, b). That project focused on quantifying relative abundances of diurnal lizards and other reptiles selected for monitoring; those data will reflect changes in

population numbers over time, but are not likely to provide insight into causes for population fluctuations, other than correlative relationships with rainfall.

The goals of this study were to acquire a detailed understanding of the annual cycles, demography, home range, diet, reproduction, and habitat used by Cowles fringe-toed lizards in the Mohawk Dunes, an area with minimal human impacts. Gathering such information now, while populations seem to be thriving, could be critical in understanding future declines, should they occur.

Population estimates

It has been stated that lizard population sizes have distinctly less variability than those of most other life forms (Schoener 1985, 1994). Schoener (1985) based this conclusion on studies of 29 populations belonging to 21 species, all that he could find in the herpetological literature with appropriate detail and study design. It is worth noting that most (25) of these studies covered only a single generation of the subject species, and thus may have missed long-term variability.

Recent studies have documented large population variations between lizard generations. These include a 19-year study of the tropical *Anolis limifrons* (Andrews 1991) and an 8-year study of the hot desert *Cnemidophorus tigris* (Anderson 1994). In both cases, fluctuation in rainfall was identified as the root cause of population fluctuation, as mediated through plant productivity, the attendant arthropod (food) abundance, and the associated nutritional status of the population.

Researchers have estimated densities for populations of *Uma notata* in Algodones Dunes (Luckenbach and Bury 1983, Maes 1990), *U. inornata* in Coachella Valley (Barrows 1993, Muth and Fisher 1991, Turner et al. 1984), and *U. scoparia* in Twenty-nine Palms Marine Corps base (Fromer et al. 1983). Their efforts involved mark/recapture, transect, and removal methods, and ranged from single- to 8-year programs. For areas of suitable habitat which were unused by off-road vehicles, their estimates averaged 3.2 - 25.8 *Uma*/ha. Muth and Fisher (1991) found "a dramatic decline" in *U. inornata* at 1 location over the course of 5 years but were unable to pinpoint a cause. Two studies which compared areas open and closed to use by off-road vehicles found significantly lower *Uma* population densities in the open areas (Luckenbach and Bury 1983, Maes 1990). Reasons offered for these declines include loss of escape cover and loss of arthropod food resources associated with the vegetation.

During this two-year study of *Uma notata*, we estimated population densities in each year. We used several estimation techniques in order to maximize the comparability of these results to those from other areas and possible future efforts in the Mohawk Dunes.

Reproduction

The best previous data showed that in California *Uma notata* hatch in late summer, and reproduction usually begins during the second summer thereafter, though a few precocial individuals may breed in late summer following the year they hatch (Mayhew 1966a). A female may lay 1-5 eggs in a clutch (mean=2.1, N=90 lizards, no SE given) from May-August (Mayhew 1966a), and might lay more than one clutch per year, though it has only been documented in captivity (Mayhew 1961, 1964a, 1966a). Similar results

were found for *U. inornata* (Mayhew 1965) and *U. scoparia* (Mayhew 1966b). The only long-term study to date (Muth and Fisher 1991) found maximum life span for *U. inornata* of 7 years, giving each female up to 5 reproductive years.

Mayhew (1966a) found that male left testis volumes vary widely through the year, reaching maximum size in May or June.

Fluctuating rainfall has been suggested as a major influence in *Uma* population size. Mayhew (1967) described significant changes in *Uma* testicular volume, egg production, and timing of reproduction, associated with annual variations in rainfall, such that dry winters led to delayed reproduction. Similar associations have been noted in other lizard species, along with changes in egg size and clutch frequency (e.g., Vitt et al. 1978, James 1991). Some desert species have been noted to forego reproduction entirely during dry years (Nagy 1973, James 1991).

The populations of *Uma notata* previously studied for reproductive patterns were all in California, where rain falls primarily in winter. In the Mohawk Dunes, an area that typically gets about half its annual rainfall in the summer, 1995 had a wet winter/spring but dry summer, while 1996 had a dry winter/spring but wet summer.

Timing and success of recruitment

Mayhew (1966a) described the first sighting of *Uma notata* juveniles in the Algodones Dunes as varying from July 16 to September 9 in the years 1959-1962. He described those years as "a period of extreme drought," but reported that juveniles were "quite abundant each year."

In contrast, Muth and Fisher (1991) reported that the number of hatchling *Uma inornata* found at one of their study sites varied from 8 to 175 per year during five years of study, in apparent response to annual rainfall which varied from 33 to 138 mm per year.

Survival

Balancing recruitment of young individuals, one of the other major factors in wildlife population dynamics, is mortality. This is commonly addressed by making estimates of its complement, the survival rate (ϕ), which is the likelihood that an animal known to be alive at one time will still be alive after a designated interval (mortality rate = $1 - \phi$). Survival rates can be measured or estimated through long-term studies that record actual mortality losses or through mark/recapture studies (Lebreton et al. 1992). The basis for many mark/recapture procedures is the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965).

Temperature and humidity effects

The paired environmental variables of temperature and humidity play critical roles in the lives of these lizards. Environmental temperatures affect morning emergence from the sand and mid-day burrowing into the sand, thus influencing the number of animals visible on the surface during a census operation. Temperatures affect all physiological processes, including egg development and seasonal events such as the onset of and emergence from hibernation. Relative humidity may influence survival in many species and may be an important proximal cue for seasonal activity patterns of many lizards and their prey.

Temperature tolerances for *Uma notata* were established by Cowles and Bogert (1944) and Brattstrom (1965), who determined from caged and field-caught specimens the minimum (26.0°C) and maximum (40.5°C) voluntary body temperatures, mean "preferred" body temperature (38.6°C), and critical maximum body temperature, which induces a loss of the righting response (45°C). Cowles and Bogert (1944) noted a correlation between first surface appearance of the lizards in the morning and the sand surface reaching 25°C. Bennett (1980) noted that *Uma inornata* displayed its fastest burst (sprinting) speed at body temperatures around 40°C. Mayhew (1964) and Pough (1970) reported that in mid-summer, lizards of the genus *Uma* have a bimodal activity cycle with peaks of activity in the early morning and late afternoon, and with no lizards visible during midday when the sand surface temperature gets well above their critical thermal maximum. They concluded that the lizards seek shelter by burrowing into sand in rodent burrows or beneath shrubs. Pough (1970) found that *Uma* regularly bury themselves to depths of 4 cm.

Maes (1990) surveyed population densities of *Uma notata* by using transects conducted while air temperatures were between 36° and 42°C, based on Bureau of Land Management criteria for "the optimal temperature window" of the species. Recent monitoring efforts for *Uma inornata* have involved walking transects when air temperatures at one cm above the surface were between 35° and 49°C (Barrows 1993).

Humidity may form another environmental constraint on lizard behavior. *Uma notata* experience 40% of their daily water loss during the average 4.7 hr that the lizards are exposed on the surface and may find relief in relative humidities approaching 100% in the sand beneath shrubs (Deavers 1972). Thus, these animals may exercise considerable behavioral control over their water budget by varying the length of time they are above or below the surface. Deavers (1972) made some measurements of relative humidity and temperature at 15 cm above the sand in the Algodones Dunes to calculate evaporative potential for surface-active fringe-toed lizards; however, the microenvironment at 15 cm above the sand is so different from that which the lizard encounters (approximately one cm above to 4 cm below the sand) that no meaningful correlations of those microclimatic measurements and behavior can be made.

Territoriality and tail loss

The extent to which spacing behaviors such as territoriality affect *Uma* population density is unclear. A review of spacing patterns in 67 studies involving 60 species of iguanid lizards described only 3 species - not including *Uma* - not found to be territorial (Stamps 1977). Tinkle (1967) noted that lizard territoriality restricts densities somewhat, but that considerable contraction of territory size may occur at high densities. Carpenter (1963) studied social organization among captive *Uma* and concluded that adult males were strongly territorial, but his results may have been affected by keeping a large number of lizards confined in a small space. Some field confirmation was given by Pough (1970) who observed, "Adult males appear to take stations on the large central dune at intervals of 50-100 feet. The intervals remained constant from day to day, but no marking experiments were carried out to determine if individual lizards occupied the same spot each day." The only long-term (7-year) mark-recapture study showed no significant territoriality (Muth and Fisher 1991).

Some have proposed that an indirect measure of male lizard territorial behavior might be the difference in frequency of tail breaks between the sexes (Vitt et al. 1974), though it has also been used as an index of predation pressure (Schoener and Schoener 1980).

Selection and characteristics of escape cover

Fidelity to certain physical structures is a common feature of reptilian ecology, often due to microclimatic cues associated with those structures (Heatwole 1977, Huey 1991). In addition, species-specific microenvironments are commonly used by lizards for escape from predators (Greene 1988).

Uma notata and its closely-related congeners, *U. inornata* and *U. scoparia*, have long been noted for their ability to hide from perceived predators by burrowing into loose sand, but published accounts (e.g., Mosauer 1935) generally also note a tendency to simply hide beneath plants or to burrow beneath the branches of plants. The dappled shade of plants apparently reinforces the lizards' cryptic coloration and buffers the potentially lethal heat of full sunlight (Stebbins 1944, Pough 1970), though no quantitative study of cover use has been published.

This portion of our study was conducted to determine if particular kinds of cover are important to *Uma notata* in escaping from perceived predators. Terminology is used in accordance with Johnson (1980), where "selection" implies the choice of a resource, in contrast to "preference" which can be determined only by offering all resources on an equal basis.

Diet

Despite some scientific attention, the diet of the genus *Uma* remains somewhat unclear. It has been commonly considered a carnivore, or perhaps opportunistic omnivore, but the data are contradictory. Stebbins (1944) gave a generalized and qualitative list of food types eaten, including both insect and plant taxa, most at the level of order or family. Smith (1946: 154) described the diet as "mostly of insects, but also includes succulent plant parts." Shaw (1950) and Carpenter (1963) noted several instances of captive *Uma* eating other lizards, including young of their own species, and Carpenter (1963) described ingestion of shed lizard skin. Cannibalism by *Uma* in the wild was described by Sugerman and Applegarth (1980). Carpenter (1963) also noted some observations of captive *Uma* eating plant material. Mayhew (1966a) suggested that "the bulk of food normally utilized by *Uma notata* consists of insects that live close to the sand surface," based on an unstated number of dissections. He made similar statements for *U. inornata* (Mayhew 1965) and *U. scoparia* (Mayhew 1966b). Minnich and Shoemaker (1972) examined the stomachs of 12 adult and 5 juvenile *U. scoparia*, collected in late July and early August, 1969. They found >90% of the items in juvenile stomachs were arthropods, primarily ants and beetles, with the remainder being small amounts of grass. But the adult stomachs contained about 60% plant materials, primarily dried seeds of an unidentified plant, with arthropods and shed *Uma* skin forming the remainder. Zalusky et al. (1980) suggested that the dentition of *Uma* is "adapted for a diet of high-activity, moderately armored prey," though they had no original diet data to support that.

Kaufmann (1982) analyzed *U. scoparia* diet by stomach flushing, examining contents of 61 stomachs gathered during April through June, 1980. Though hard to decipher, his results suggest that invertebrates comprised most of the diet, with plant matter contributing 29% by volume for adult males, 8% for adult females, and 3% for juveniles. Pianka (1986: 169) found plant material comprised 13.3% by volume of the diet for *U. scoparia*, based on 32 lizard stomachs examined.

More recently, Durtsche (1992, 1995) looked at foraging behavior in *U. inornata* during May and July 1986, attempting to find diet changes due to presumed differences in reproductive status and food abundance. Much of his analysis was based on stomach flushing of 80 adult animals (40/month). He found plant matter in the May diet made up 71% by frequency or 59% by dry mass, while the July diet contained 43% and 38%, respectively.

Up to that point, all published reports on *Uma* diet were from California populations, with the strongest evidence pointing toward omnivory with a slight predominance of plant matter among adults, and with a suggestion of more insect-oriented diets for juveniles. But in the study with the largest sample size (83 stomach contents), the largest temporal span (Oct. 1982, June 1983, and July 1984), and a site outside California (Pinacate, Sonora, Mexico), Ortega-Rubio et al. (1995) found no plant matter in the diet of *Uma notata*. They reported a purely insect diet. In sharp contrast, a study of the more distantly-related Mexican species, *Uma paraphygas*, found plant parts in nearly 56% of the 153 lizards examined, providing more than 40% of the total prey volume for adult males in 2 of 4 seasons (Gadsden and Palacios-Orona 1997).

The volume of plant material described in some of these reports is far greater than for most other North American desert lizards. In an analysis of 11 North American desert lizard species, Pianka (1986: 169) showed *Uma* to be second in plant consumption only to *Dipsosaurus dorsalis*, an herbivore.

Herbivory in lizards has been linked to body size, with Pough (1973) suggesting that species which weigh more than 300 g are almost all herbivores while those weighing less than 50-100 g are carnivores, and that the young of herbivorous species tend to be carnivorous until they reach weights of 50-300 g. Several small species are exceptions to those rules, including both omnivores and herbivores which average 50 g or less (Búrquez et al. 1986, Greene 1982). *Uma notata* is another exceptional omnivore with an adult mass of about 30 g (Pough 1973).

Several omnivores also appear to make an ontogenetic dietary shift from juvenile carnivory to adult omnivory (Mautz and Nagy 1987), and the scant existing data for juvenile *Uma* suggest the same for this genus (Kaufmann 1982, Minnich and Shoemaker 1972).

Study Area

The Mohawk sand dune field lies about 65 km east of Yuma, Arizona, on the eastern side of the Mohawk Valley. The elongated dune system runs parallel to and west of the Mohawk Mountains, trending northwest to southeast. The dune field is about 32 km long and varies in width up to 3.2 km wide, covering roughly 7,770 ha. It reaches a maximum elevation of 207 m (680 feet) above sea level near the center of the dunes, rising about 55 m (180 ft) above the surrounding desert. It consists of windblown sand on a

network of lightly vegetated ridges ("crests") which surround small depressions ("swales").

The Mohawk Dunes lie within the Lower Colorado River Valley subdivision of the Sonoran desertscrub community (Turner and Brown 1982). They are relatively well-vegetated for sand dunes in the region, and bear a strong vegetative similarity to the dune communities of the Gran Desierto in Mexico (Felger 1980, Felger et al. *in prep.*).

Inventories were recently conducted and baseline data gathered on the Mohawk Dunes flora and herpetofauna as part of a research program conducted simultaneously with that reported here (Turner et al. 1997 a, b). During that study we found mean ground cover on the dune crests ranging from 7 to 15%, while that in the swales was about 9%. Dominant perennial species on the crests included *Ambrosia dumosa, Aristida californica, Hilaria rigida, Ephedra trifurca,* and *Psorothamnus emoryi.* The swales had a similar suite of species, with the addition of *Larrea tridentata* and a strong reduction in *Psorothamnus emoryi.*

The swales are also notable for having a much more stable surface. This is largely maintained by a well-developed microbiotic crust dominated by the cyanobacterium *Microcoleus vaginatus* and the lichen *Collema* sp. (J. Belnap, pers. comm.).

As part of the plant monitoring effort, we took photographs for future comparison at 9 sites in the Mohawk Dunes in 1995 and 1996 (Turner et al. 1997a). The primary repository for those was the Environmental Programs Flight, Luke Air Force Base, Arizona, with duplicate copies kept by Turner and Schwalbe.

Air temperature regimes for the area are typical of the lower Sonoran Desert, with mean daily maxima of 40 - 43°C for June through September, and peaks in excess of 49°C not uncommon in midsummer (Sellers and Hill 1974). Surface temperatures on the dunes reach greater extremes, with June and July maxima averaging above 65°C in 1996 (unpubl. data).

Annual rainfall averaged 10.54 cm (4.15 inches) at the nearest weather station, Mohawk, from 1900-1951. About half of that, 4.85 cm (1.91 inches), fell in the May-October warm season, primarily in July-September, while 5.72 cm (2.25 inches) fell in November-April (Sellers et al. 1985). Months with no rain are common, but summer storms can deliver a large fraction of the total annual precipitation in a short period. One such storm dropped 9.01 cm (3.55 inches) on Mohawk on August 10, 1941 (Sellers and Hill 1974). Our data from 3 rain gauges around the Mohawk Dunes (Fig. 1) show an average rainfall of 6.96 cm (2.74 inches) during 1995, with virtually all of it falling before May. Aside from a few small showers, 15 months passed before the next significant rainfall. The area did receive summer rains in 1996, but the yearly total was well below average.

The Mohawk Dunes and surrounding landscape are part of the Barry M. Goldwater Air Force Range, jointly managed by Luke Air Force Base and the Yuma Marine Corps Air Station. Military activities in the area have very little apparent effect on the dune biota, and limitations on civilian access appear to have provided substantial protection from the damaging recreational activities common to other dune systems in the American Southwest.
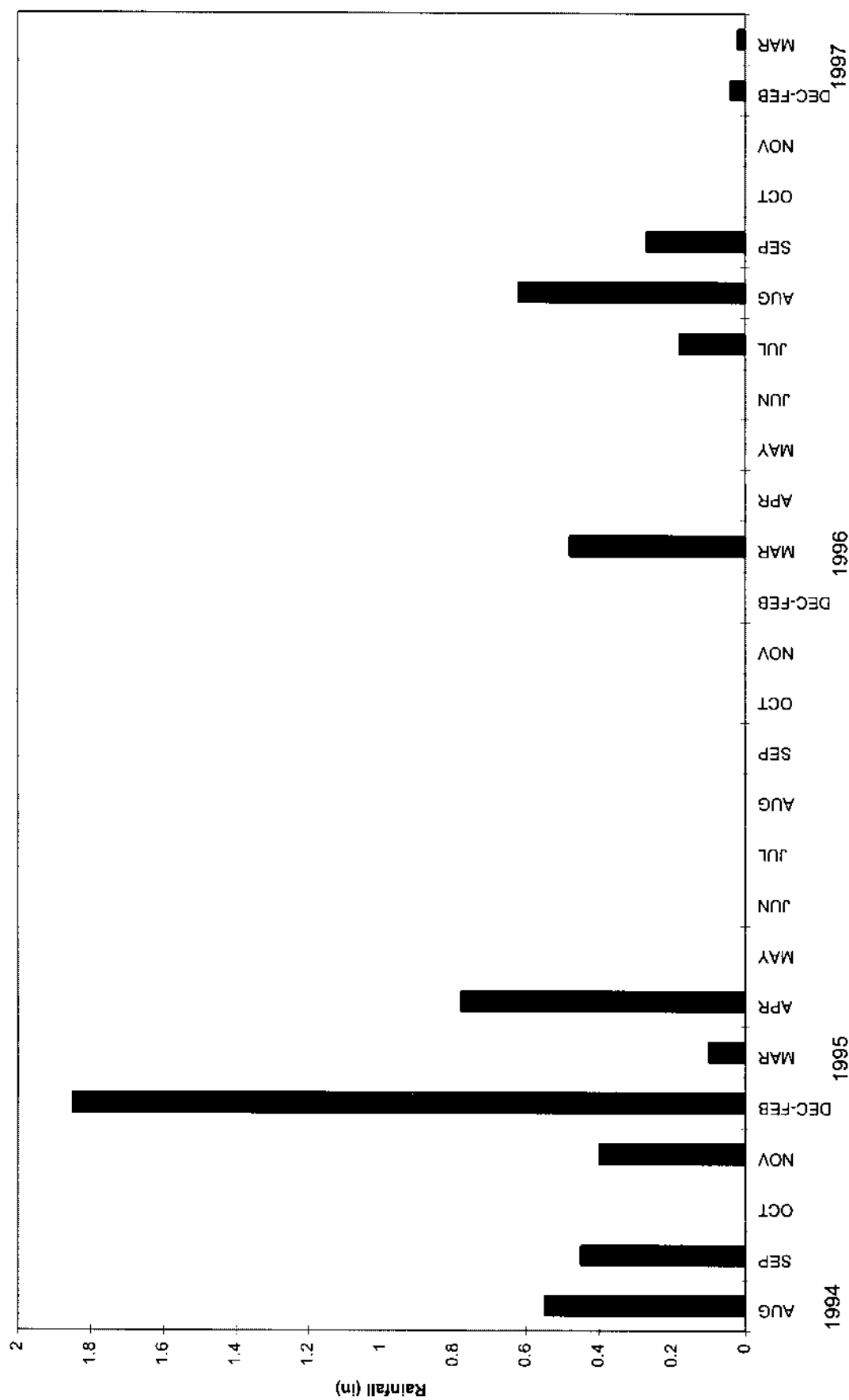
Figure 1. Monthly rainfall, Mohawk Dunes, **AZ.** Rain gauge located at Playa site, near the study grid.

Methods

Field effort

Forty-one working trips were made to the Mohawk Dunes during the course of this and related projects, from February 1994 through March 1997. Total field effort for the trips comprised 446 person-days over 147 calendar days. This includes 77 person-days of volunteer time specifically related to this project.

Study grid

A 2-ha study plot, 100 by 200 m, was established on a dune crest in occupied habitat of *U. notata*. The plot was divided with stakes into a grid of 10-by-10-m cells, and the stakes were uniquely labeled according to alphabetic and numerical axes.

An instrument shelter was placed near the center of the grid. This contained temperature and humidity data loggers (Appendix 1) to record conditions at 1.5 m off the ground. Additional data loggers were placed <10 m away to record temperature (shaded) and humidity at 2 cm above the sand surface, temperatures at the sand surface in full sun and under a shrub (*Psorothamnus emoryi*), and temperatures 2 cm beneath the sand surface in full sun and under the same shrub.

Vegetation survey

Available cover was estimated for each cell in the study grid during June 1996 using a variation of a listing square (Bonham 1989:101). Each observer was equipped with 2 short (ca. 1.2 m) cane poles, each marked at 1 m. Holding the poles at right angles to form 2 sides of a 1-m square, an observer would encompass blocks of vegetation and visually gauge the number of square meters for a particular cover type within the cell. Fractions of a square meter were summed, with the total rounded to the nearest whole number. Results for all cells were averaged across the grid.

These results were checked in March 1997 by making more precise estimates of foliar cover (Bonham 1989:124) of all plants within a randomly-selected 10% (n=20) of the cells. The long axis of each plant clump (D_1) was measured with a hand-held tape, along with the widest expanse on an axis at right angles to the first (D_2). Each clump was assumed to be an ellipse with the diametrical axes as measured, so its area was calculated as:

$$area = \pi\left(\frac{D_1+D_2}{4}\right)^2.$$

Values for each species were summed for every cell, and the totals compared to earlier estimates for the same cells.

Lizard surveys

An initial 1-week lizard census was made of the grid and of a 10-m buffer zone around it in April, 1995. All fringe-toed lizards captured were marked by toe clipping for permanent identification. Adults also had a unique combination of colored beads sewn onto the dorsal surface of their tails to allow visual identification without physically recapturing them (Fisher and Muth 1989), while juveniles (<60 mm SVL) had identification numbers marked on their backs with a non-toxic black pen (Sanford

Sharpie™). When the temporary markings were shed, the lizards were re-marked with ink until large enough to be beaded.

Belt-transect census efforts were conducted on the study grid during April through October, 1995, and April through August, 1996. Census efforts were conducted in the morning, beginning when surface temperatures exceeded the minimum voluntary body temperature (18.0°C) for the species, or in the evening after surface temperatures were below the maximum voluntary body temperature (40.5°C) (Brattstrom 1965). For each census, two or more researchers walked in parallel, passing through all rows of the grid, tapping with noosing poles at the base of shrubs to flush all surface-active lizards.

Every lizard sighted was visually identified using binoculars, but was usually captured only if no marks were visible. The lizard's identity was noted, along with its location on the grid, the time, air and ground temperatures, distance from cover, and cover type (plant species or dead woody debris) nearest the point where the lizard was first observed. If the lizard was running when observed, data were taken for the starting point of the run, as determined by its tracks. Proximity to cover and distance run were also estimated for the spot where the lizard first stopped moving. This spot was assumed to be their intended destination, as previous observations had shown that *U. notata* tend to make one quick dash and then freeze, remaining in an open spot or clump of vegetation until the perceived threat has passed or until threatened again. Two observations of an individual in a single day were recorded only when one was in morning and the other in evening, as these were separate periods of lizard activity divided by an inactive phase during the heat of mid-day.

After the initial capture, we attempted to recapture all lizards at least once each fall and spring. On each capture occasion, we used a ruler or tape to measure the animal's snout-vent and tail length, noted whether its tail was broken, and measured any tail regrowth. We weighed the lizard using a Pesola hand-held spring scale. Adult females were palped for the presence of eggs. For those with beads attached, we examined the suture for indications of infection or tearing; on the few occasions where the beads were found to be loose, they were removed and reattached, usually on the opposite side of the tail. No indication of infection or tail loss due to bead attachment was found.

Much of the grid and lizard survey design was similar to that used in ongoing studies of the Coachella Valley fringe-toed lizard (Muth and Fisher 1991) in order to provide comparable results.

Pitfall traps

Lizards were captured with 6 trap arrays, each consisting of 4 pitfall traps and some with an additional 6 funnel traps (Campbell and Christman 1982, Gibbons and Semlitsch 1982). Pitfalls were 18.9-l (5-gallon) buckets sunk to their rims in the ground. These were placed in arrays, each consisting of a central pitfall circled by 3 others which were distributed around the center at roughly 120° angles with radii of 7.7 m. Four arrays had low metal drift fences connecting the central pitfalls with their outliers. Pitfalls were occasionally augmented with funnel traps made from metal screening and placed along the drift fences. Two arrays with drift fences were placed in dune swales, with the remaining 4 on crests. Trapping effort comprised 912 trap-days (228 array days x 4 traps each).

Lizard collections

To determine diet and reproductive cycles in *Uma notata*, lizards were collected on a monthly basis during April through September, 1995, and March through August, 1996. Lizards were captured by trapping, noose, or hand, or with pistol shot. Their body temperature was measured immediately unless the capture process took long enough for the temperature to change substantially, and temperatures were taken of the ground surface and the air at 5 mm and 1.5 m off the ground. When necessary, lizards were euthanized by thoracic injection of sodium pentabarbitol (Nembutal). Lizards were weighed, measured, and described in terms of reproductive condition and any unusual conditions. All specimens were clipped or sliced open, fixed in the field by immersion in a buffered 10% formaldehyde solution (formalin) for approximately 24 h, cleared by immersion in water for approximately 24 h, and then preserved in 55% isopropanol for later dissection (Pisani 1973).

After dissection and analysis in the laboratory, all lizards were stored with their respective parts in individual plastic whirlpacks, in case questions arose later. All specimens of *Uma notata* collected from the Mohawk Dunes will ultimately be deposited at the University of Arizona Herpetology collection (UAZ), where they have been assigned sequential numbers from UAZ 50387 through 50559.

Demographics

Mayhew (1966) identified 5 classes of *Uma notata* based on gender, SVL, and size at sexual maturity: juveniles (up to 50 mm), immature females (51-69 mm), immature males (51-79 mm), adult females (70+ mm), and adult males (80+ mm). These divisions were used for data analysis in several aspects of this study.

As a measure of physical condition, we calculated mass-length regressions on marked and collected lizards. Since body volume is a cubic function and mass increases in a curvilinear relationship to length, regressions were calculated using total mass for each lizard as a variable dependent on the cube of its snout-vent length (Fellers et al. 1988). After separating the data by sex, year, and season (where spring = March-June and fall = July-October), the resulting regressions were compared using 2-tailed t tests. Comparison t tests were calculated first on slopes of the regression lines. If the slopes of a pair of lines were not significantly different, then a t test was used to determine whether the lines have the same elevation (i.e., the same vertical position on a graph)(Zar 1996).

For analysis of demographic and home range patterns, observations of *Uma* on the study grid were divided into "residents" - those lizards seen ≥3 times on the grid in a given year - and "transients" - those seen ≤2 times on the grid in a given year. Some were placed in the latter category, though they could easily be considered "semi-transient" in that they were seen ≥3 times on the grid over the course of the study, but were seen only once or twice in one or both years.

Population estimates

As part of a related study conducted for the U.S. Air Force, we designed a protocol for monitoring the Mohawk Dunes *Uma* population. This was based on a single observer walking belt transects along fixed, 0.5 or 1 km curvilinear routes through *Uma* habitat, and was intended to allow identification of gross changes in this index of

population density (Turner et al. 1997a). Baseline data were gathered at two sites in the Mohawk Dunes, with transects walked monthly throughout the warm seasons in 1995 and 1996. Simple estimates for minimum population densities can be derived from these data by the calculation:

1,000 m transect length X 10 m transect width = 10,000 m² = 1 hectare
thus, # seen/km transect = #/ha.

Muth and Fisher (1991) made a comparison of four population estimation techniques using baseline data from repeated censuses of *Uma inornata*. They compared calculated estimates to known population sizes. In comparison to the Jolly Stochastic Method, the Manly-Parr Method, and a Calibrated Incomplete Count Method, they found the most accurate estimator was an empirically derived correlation, the 20% Active Estimate. This was derived from 4 years of a mark-recapture study which demonstrated that about 20% of the known population was visible during the appropriate thermal period on any given day. They estimated the population size by multiplying 5 times the average daily number of lizards sighted for each month, and found that estimate to fall within the 95% confidence interval of the estimate from the mark/recapture study for most months.

Muth and Fisher (1991) recommended trying the population estimation procedure developed by Minta and Mangel (1989) for capture-resight studies, though they did not use it on their data. We used the program NOREMARK (White 1996) to calculate Minta-Mangel estimates for the *Uma* population on the study grid. This procedure does not assume equal probabilities of resighting marked individuals, though it does assume a closed population. It uses a bootstrap procedure to compute a confidence interval around the estimated value.

Reproduction

For adult male lizards, we weighed testes and measured testis length and width to estimate volume using the formula for a prolate spheroid:

$$volume = 4/3\pi(1/2 \text{ length})(1/2 \text{ width})^2$$

(Mayhew 1966a). Unlike Mayhew (1966a), volumes of both testes from each lizard were used in subsequent analysis, in order to portray the natural variation present.

For adult female lizards, we counted vitellogenic follicles and oviductal eggs, then measured egg lengths and widths to estimate volume as above (Mayhew 1963, 1966; Vitt et al. 1993).

Survival

To generate survival estimates, we used two programs to analyze the mark/recapture data from the study grid for each year. Program RELEASE (Burnham et al. 1987) analyzed the data for their goodness of fit within the Cormack-Jolly-Seber model. Program SURGE (Lebreton et al. 1992) generated survival estimates and recapture probabilities. To reduce the effect of day-to-day variability in resighting results and increase the biological significance of survival estimates across each year of the study, sightings were combined for all census efforts within each multi-day field trip. Thus, an animal was noted as present in a given week whether it was seen once or several times.

Home range

A variety of methods have been devised for determining home range area from mark/relocation data, none being perfect for all applications or species. The minimum convex polygon (MCP) method, while old, has been recommended for lizard studies (Rose 1982, Waldschmidt 1979) and was used here with program CALHOME (Kie et al, 1994). The major drawback of MCP analysis is a sample-size bias which produces increasing polygon sizes with increasing sample size, up to some asymptotic value which approximates the complete home range of an individual, assuming the lizard actually restricts its activities to a discrete area (Rose 1982). Jennrich and Turner (1969) calculated a series of correction factors for adjusting observed home ranges to their expected asymptotes, but this was shown to overestimate actual values derived from empirical data (Rose 1982). For part of our analysis and comparison with other studies, we used a modification of the Jennrich and Turner (1969) technique which sets the asymptotic sample size at 16 observations (Appendix 3), an empirically determined value from other studies (Christian and Waldschmidt 1984).

Territoriality and tail loss

We analyzed the incidence of tail loss (regardless of amount of regrowth, not including losses due to our capture) among lizards collected as specimens and from the first captures of those which were marked. Those 2 samples were compared using a 2-tailed t test to determine if they could be pooled. The data were then separated by sex and size class for comparisons using t tests and visual inspection of the resulting graphs.

For this analysis only, the same size classes were used for both sexes, with juveniles being <50 mm SVL, immatures as 50-69 mm, and adults as ≥70 mm. Use of consistent size categories between sexes was chosen in order to identify any effects of size-based competition or predation, which might be missed by using differential size classes based on reproductive status.

Selection and characteristics of escape cover

The primary data set used here was gathered from observations on the study grid, an area deliberately placed in what appeared to be good *Uma* habitat. It did not include a significant part of any swale. Supplemental data were gathered during collection of specimens, wherever they were found in the dune field.

Cover selection was determined by comparing proportional use and availability with an overall chi-square goodness-of-fit test, and the use of individual cover types was analyzed by use of Bonferroni procedures to construct simultaneous confidence intervals around the observed use of each type (Neu et al. 1974, Byers et al. 1984, Thomas and Taylor 1990). Each statistical test was performed with a potential error rate of $\alpha = 0.05$.

Lizards were assumed to have selected a patch of cover only if they stopped under its canopy (i.e., distance to cover = 0 m). This conservative approach does not incorporate the common events where lizards ran around shrubs and stopped opposite them from the observer, close to but not quite under the shrub canopy.

Diet analysis

In the laboratory, each specimen's stomach was removed and emptied. We separated plant material from animal material, watching for endoparasites. Invertebrate parts were identified to the lowest possible taxonomic level by W. Eugene Hall of the Entomology Department, University of Arizona, and plant parts were identified by Turner, with assistance from R. Felger, P. Jenkins, and T. VanDevender.

Once identified, we counted prey items by taxon and measured length and width (to the nearest 0.01 mm) of each item using electronic calipers. We estimated the volume for each item or group of items using the formula for a prolate spheroid:

$$volume = 4/3\pi(1/2\ length)(1/2\ width)^2$$

(Vitt et al. 1993). When the major parts of a disarticulated arthropod appeared to be present, measurements were made on a crude reassembly of the animal. Otherwise, only the isolated parts present (e.g., a single grasshopper leg) were measured, with no assumption that the remainder of the animal was consumed; the exception to this was ants, where the presence of a head was considered evidence that a whole ant had been eaten. For the common ant taxa, an average volume was used after being calculated for each species from measurements of a series of field-collected individuals.

The volume of arthropod material was divided by the total volume of the prey items for each specimen to identify the relative proportion of arthropod to plant materials. To identify sexual differences, these proportional values were analyzed using 2-sample Student's t-tests (Microsoft Excel) in a series of pairwise comparisons between males and females of each size class. To test for ontogenetic and seasonal trends, linear regression tests (JMP-IN) were performed, with the proportional values regressed against body size or date for each sex. A significance level of $\alpha = 0.05$ was used for all tests.

No attempt was made during this study to measure availability of prey items, as the abundance of particular prey species was assumed to vary across the dune field in response to localized rainfall or other influences.

Demographics
Results

During this study we marked 52 *Uma* on the grid, 4 near the grid, and an additional 34 in pitfall traps. In addition, we collected 157 from localities widely scattered around the Mohawk Dunes.

Using the combined data set of collected lizards and marked lizards at first capture for each year, body size and mass differed between years, with both sexes appearing to average smaller and lighter in 1996 than in 1995 (Tables 1, 2). The size difference is an artifact of more juvenile and immature animals in the 1996 sample, as there was no significant size difference between years for adults of either sex (female mean SVL=74.8 mm for both years, t=0.056, df=45, 2-tailed p=0.955; male mean SVL=92.8 mm (1995) and 91.4 (1996), t=1.139, df=66, 2-tailed p=0.259).

There were, however, significant differences in body mass. The mass-length regressions showed no significant differences between the sexes in either slope or elevation during either year (see Appendix 7 for statistical values of these and subsequent tests), so the sexes were combined for subsequent tests. High coefficients of determination (r^2 values) when the sexes are considered separately or together imply that

they share a common mass/length relationship. Comparing regressions on the combined data sets showed significant differences between lizards measured in 1995 and 1996. Breaking the data into seasonal subsets showed a significant difference between the regressions for spring and fall of 1995, with lizards heavier for a given length in the spring. There were no significant differences between spring and fall of 1996. The regression for spring of 1995 was significantly different from that for spring 1996, with lizards heavier in 1995. Likewise, the regression for fall of 1995 was significantly different from that for fall 1996, with lizards heavier in 1995.

Table 1. *Uma notata* snout-vent length (mm), Mohawk Dunes, AZ. These include data from collected lizards and from first captures of marked lizards.

	Mean	SE	Median	Range	N
1995					
Male	78.9	2.5	88	35-100	60
Female	66.5	1.3	69	36-83	68
1996					
Male	73.8	2.5	80	41-102	65
Female	61.7	1.3	65	44-80	68

Table 2. *Uma notata* body mass (g), Mohawk Dunes, AZ. These include data from collected lizards and from first captures of marked lizards.

	Mean	SE	Median	Range	N
1995					
Male	18.24	1.37	19.4	1.2-35.3	60
Female	10.29	0.48	10.2	1.5-18.1	68
1996					
Male	13.23	1.05	13.4	2.0-28.9	65
Female	7.16	0.42	7.4	2.2-14.1	68

We marked few juveniles during 1995, and none of them were seen ≥ 3 times that year (Table 3). The ones we did see appeared in mid- to late summer, normally a rainy season.

The number of grid residents identified was higher in 1996 than 1995 (Table 4), while the number of transients declined (Table 5).

Another pattern is the large number of immature transients seen in 1995, and the much smaller number in 1996 (Table 5).

Table 3. All *Uma notata* seen on the study grid in a given year.

	1995			1996		
	Male	Female	Total	Male	Female	Total
Adult	6	6	12	5	7	12
Immature	7	12	19	2	9	11
Juvenile	3	1	4	6	3	9
Total	16	19	35	13	19	32

Table 4. Grid residents: *Uma notata* seen ≥3 times on the study grid in a given year.

| | 1995 | | | 1996 | | |
	Male	Female	Total	Male	Female	Total
Adult	0	5	5	2	3	5
Immature	3	3	6	1	5	6
Juvenile	0	0	0	4	2	6
Total	3	8	11	7	10	17

Table 5. Grid transients: *Uma notata* seen ≤2 times on the study grid in a given year.

| | 1995 | | | 1996 | | |
	Male	Female	Total	Male	Female	Total
Adult	6	1	7	3	4	7
Immature	4	9	13	1	4	5
Juvenile	3	1	4	2	1	3
Total	13	11	24	6	9	15

Combining the residents and transients, the total number of adults seen on the grid was identical in the two years, and the sex ratio of adults was nearly so. Combining all age classes, we found fewer males than females each year: 16 male:19 female for 1995 and 13:19 for 1996 (Table 3).

Another demographic data set was obtained by operating pitfall trap arrays (Table 6). We captured 34 individuals total, 3 of which were caught both years. While not directly comparable to the grid observations, it is interesting to note the 63% drop in number of individuals caught between 1995 and 1996.

Table 6. *Uma notata* captured in pitfall traps.

| | 1995 | | | 1996 | | |
	Male	Female	Total	Male	Female	Total
Adult	6	7	13	4	1	5
Immature	2	7	9	1	1	2
Juvenile	4	1	5	1	2	3
Total	12	15	27	6	4	10

Discussion

Maximum snout-vent lengths were well below the male (121 mm) and female (94 mm) maxima reported in the literature (Mayhew 1966).

Springtime differences in the mass-length regressions matched the observed rainfall patterns. Lizards were fatter in spring 1995, following a wet winter, than in spring 1996 after a dry winter.

However, the sampled lizards were fatter in fall 1995, despite a dry summer, than in fall 1996, which had normal summer rains. This may be due to differential fat storage from the respective spring seasons, or greater food availability in fall 1995 as a long-term result of that year's wet spring.

The larger number of immature transients seen in 1995 than in 1996 may be related to the failure of the summer rains in 1995 and resulting low juvenile survivorship, since none of the juvenile transients marked in 1995 reappeared as immatures in 1996.

Within the study grid, we marked a total of 25 male and 27 female *Uma* individuals, a sex ratio of 1.00:1.08. This is not significantly different from a 1:1 ratio

(p=0.78, χ^2=0.077, 1 df). Over the course of the study, we had 84 male and 97 female resightings or recaptures on the grid, a recapture rate of 1.00:1.07. This is also not significantly different from even (p=0.33, χ^2=0.934, 1 df).

It is interesting to compare this with the long-term studies of *Uma inornata* being conducted around Palm Springs, CA, by Allan Muth and Mark Fisher. They have marked over 1,000 Uma in their study area, finding an almost even sex ratio, but their recapture rate for marked animals has run approximately 1.00 male:1.50 female (Mark Fisher, pers. comm.). Their data clearly suggests differential capturability, which might be enough to affect population estimation techniques that assume equal capturability.

The drop in pitfall captures may be related to lack of rainfall in summer 1995 and spring 1996, though it might also be an artifact of lizards in the area learning to avoid pitfalls. Over the course of 288 trap-days (72 array-days x 4 traps/array), 24 *Uma* were caught in pitfalls and marked by toe-clipping. Of those, 20 were never recaptured while the remainder were caught 2, 2, 4, and 5 times, respectively. This could be caused by learning and avoidance of the traps by most *Uma*, combined with learning and willful entry into traps by a few.

Population estimates

Results

Linear transects were walked throughout the warm seasons from July 1994 through June 1996 (Appendix 8). Simple transect-based estimates were calculated by averaging results from all years (Table 7). Using peak values from the two spring seasons (when activity levels were highest), the value for May 1995 transects gives *Uma* density estimates of 8/ha at the Crash Site, 6/ha at the Playa Site, and 7/ha overall. Values for April 1996 give estimates of 3/ha at the Crash site, 6/ha at the Playa Site, and 4.5/ha overall. These calculations optimistically assume that all lizards on the transects were active and observed, and so are almost certainly underestimates.

Our mark/recapture efforts are very similar to those of Muth and Fisher (1991), and yield an average daily sighting rate for all months in 1995 of 5.57 *Uma notata* on the 2-ha plot. Using their 20% Active estimator (5.57 x 5) gives a value of 27.86 *Uma* in the study plot (with a discrepancy caused by rounding), or 13.9 *Uma*/ha. In 1996 we had an average daily sighting rate of 5.2, yielding an estimate of 26.1 for the plot or 13.1 *Uma*/ha.

For 1995, the Minta-Mangel procedure produced a population estimate of 15 *Uma* per hectare, with a 95% confidence interval of 14-19/ha. Data for 1996 produced an estimate of 17/ha, with a 95% CI of 15-21/ha. These estimates are 2.5 and 3 times, respectively, the simple transect estimates from the playa site transect which passed through the study grid.

It should be noted that both of these estimates are very similar to the total number of individuals seen on the 2-ha grid in these years (Table 3).

Table 7. *Uma notata* seen (# per km) on transects, Mohawk Dunes, 1994-96.

Site	Mean ± SE	Range	N
Crash N & S	4.2 ± 0.5	2 - 8	12
Playa crest	3.1 ± 0.5	0 - 6	16
All combined	3.6 ± 0.3	0 - 8	28

Table 8. *Uma* population densities in Mohawk Dunes and other areas.

Location	Study method	Study period	Average (*Uma*/ha)	Range (*Uma*/ha)	Study
Mohawk Dunes	mark/recapture (Minta-Mangel)	1995	15	14-19	this study
"	mark/recapture (Minta-Mangel)	1996	17	15-21	"
"	mark/recapture (20% active)	1995	13.9	-	"
"	mark/recapture (20% active)	1996	13.1	-	"
"	transect	May 1995	7.0	6 - 8	"
"	transect	April 1996	4.5	3 - 6	"
"	transect	combined 1994-96	3.6	0 - 8	"
Yuma Dunes	transect	May 1996	9.0	7 - 10	"
"	transect	June 1996	9.25	6 - 15	"
Algodones Dunes closed to ORVs	transect	1990	3.17	0.69 - 8.63	Maes 1990
"	removal	1977, 1979	15.2	4 - 31	Luckenbach and Bury 1983
Algodones Dunes open to ORVs	transect	1990	2.1	0 - 6.90	Maes 1990
"	removal	1977, 1979	3.1	0 - 11	Luckenbach and Bury 1983
Coachella Valley	transect	1986-93	3.8	0 - 24	Barrows 1993
"	mark/recapture	1985-89	-	15 - 47	Muth and Fisher 1991
"	mark/recapture	1980	25.8	4.4 - 45.5	Turner et al. 1984
29 Palms	transect	1983	7.8	5.3 - 12.5	Fromer et al. 1983

Discussion

These population estimates allow comparison to several other studies on different *Uma* populations (Table 8).

Using the Minta-Mangel estimates, we calculated a very rough estimate of the total *Uma* population in the Mohawk Dunes. In doing so, we recognized that local population densities may vary across the dune field in response to local variations in rainfall, vegetation, or other factors. In addition, we factored out the unmeasured proportion of the dune field composed of swales, which are essentially unused by *Uma*. Using U.S. Geological Survey orthophoto quads of the area, we measured swale widths on three north/south line intercept transects across the dune field covering approximately 13.4 km total. By that measure, swale bottoms covered approximately 41% of the horizontal area in the dune field. The actual swale bottom surface area would be a lower proportion of the 3-dimensional surface area, given the rolling hills that form the dune crests, but this allows a conservative overall estimate of *Uma* habitat as:

7,770 total ha in the dune field X 0.59 = 4,584 ha of *Uma* habitat, yielding a total population estimate of 68,760 *Uma* in 1995 and 77,928 in 1996.

In addition to the population estimators used above, we initially proposed to use a modified Lincoln Index of population size (Muth 1987). However, the marked differences between number of *Uma* seen on the grid on a given day and those known to reside there, as described above, clearly demonstrate that there was not an equal probability of observing all animals on the grid during any census effort. Using the total number of individuals seen in a year (Table 3), we averaged sighting 16% of the population during any given census in each year. Using just those known to be resident (Table 4), we averaged sighting 51% in 1995 and 31% in 1996. Since equal probability of sighting (= random sampling) is a fundamental assumption of the Lincoln Index (Seber 1973), that method now appears inappropriate.

We also proposed to include a removal procedure for population estimation as part of this study. Our plan was to use approximately 70 m of metal flashing to enclose plots of approximately 400 m², with the intent to completely census and collect the *Uma* population therein. Our marking efforts on the study grid quickly showed that population densities were far too low for this approach to work. The Minta-Mangel estimates above suggest that such an enclosure, 0.04 ha, would yield between 0.60 and 0.68 *Uma*, clearly insufficient to show declining returns during a multi-day removal effort. Increasing the enclosure size enough to provide a meaningful sample size would have required hauling and erecting an amount of fence material that was logistically impossible for a study of this scope.

Biomass estimates

The biomass of *Uma notata* on the study grid was estimated by combining the masses of lizards as measured at their first captures for each year. Since the total number of *Uma* seen on the grid each year was very close to the population estimates, we combined their masses to produce a biomass estimate of 210.7 g/ha in 1995 and 148.0 g/ha in 1996.

Effect of collections

A total of 159 *Uma notata* were collected from the Mohawk Dunes for this project (though not all were suitable for all forms of analysis, so sample sizes vary). An additional 10 were collected there by others for different purposes and subsequently donated to this project. These 169 lizards taken during 3 years (1 in 1994, 77 in 1995, 91 in 1996) represent approximately 0.1% of the Mohawk Dunes population in a given year, using the estimates above. They were collected at localities in 22 different legal sections scattered widely throughout the dune system, with an average of 7.2 lizards collected per section (0.028 *Uma*/ha) or <0.2% of the populations in those sections. None were taken from <1 km distance from the study grid, pitfall trap arrays, or monitoring transects, to avoid influencing population estimates and other study objectives.

Reproduction

Results

We collected 25 adult males in 1995 and 23 in 1996 with testes suitable for analysis. Of these, 4 had only a single measurable testis each, the other having been damaged during collection.

In 1995, adult male testicular volume was high in April and May, then dropped sharply to dormant levels by the first of September (Table 9, Fig. 2). In 1996 testicular volume was relatively low, reaching its peak in May and declining more gradually through the summer.

To determine if these between-year differences may have been influenced by different body sizes of the males sampled in the 2 years, we compared snout-vent lengths for the samples. Lizards in the 1995 sample averaged slightly larger (mean SVL=93.1, SE=1.04, N=25) than those in the 1996 sample (mean SVL=92.7, SE=1.04, N=23), but the difference was not significant (p=0.756, t=0.312, DF=46).

Table 9. Reproductive condition of adult male *Uma notata*.

	1995 N (lizards)	Mean testis volume (mm^3)	SE	1996 N	Mean testis volume (mm^3)	SE
April	2	123.5	32.8	6	44.0	4.2
May	8	122.9	7.0	6	73.3	9.5
June	6	95.2	11.3	5	44.0	12.0
July	6	43.6	5.4	5	37.3	8.5
August - Sep.1	3	8.2	2.2	1	26.3	2.4

We collected 27 adult females in 1995 and 21 in 1996. In 1995, females had oviductal eggs or vitellogenic follicles from April through July with a peak in May, but in 1996 females had oviductal eggs or vitellogenic follicles only in July and August (Table 10). Only one female in 1996 was found with oviductal eggs. Minimum SVL for reproductive females was 66 mm. Mean clutch size was 1.85 eggs (range 1-3, SE 0.15, N=13).
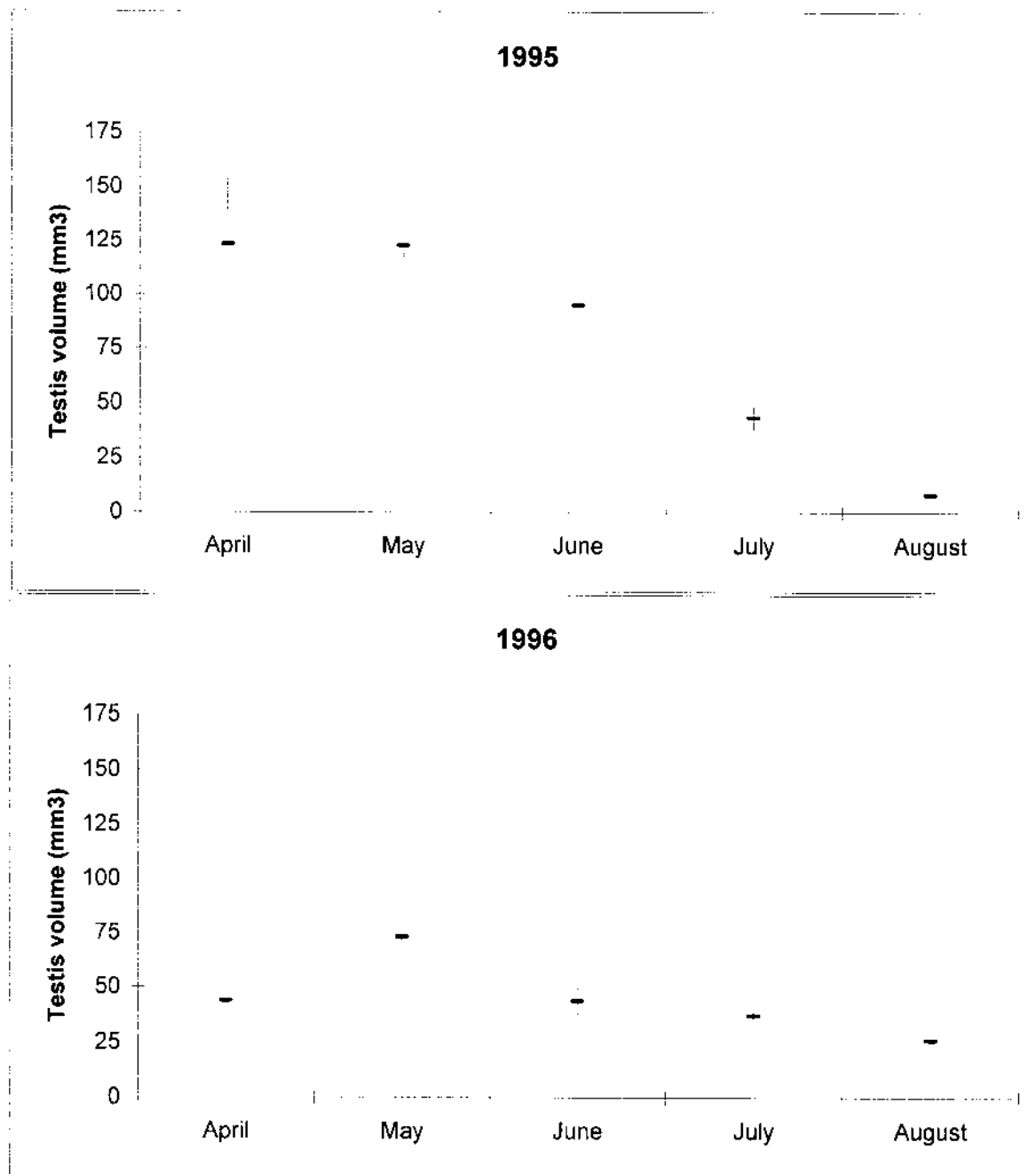
Figure 2. Reproductive condition of adult male *Uma notata*, Mohawk Dunes, AZ. Graphs show mean testicular volume (mm³) ± 1 standard error. Data include both testes for each lizard, where present, or a single testis in 4 cases where the other was damaged during collection.

Table 10. Reproductive condition of adult female *Uma notata*, Mohawk Dunes, AZ.

	1995			1996		
	N	# with eggs	# with yolked follicles	N	# with eggs	# with yolked follicles
March	0	--	--	1	0	0
April	2	2	1	5	0	0
May	10	6	7	3	0	0
June	9	3	2	4	0	0
July	5	1	0	3	1	0
August	0	--	--	5	0	3
September	0	--	--	0	--	--
October	1	0	0	0	--	--

Discussion

It appears that the rainfall patterns during this study strongly affected reproductive activity in *Uma notata*, probably through the proximate mechanism of nutritional status. Egg production and testis volumes were much higher in spring 1995 than in spring 1996, a pattern similar to the lizards' physical condition in those seasons, as suggested by comparison of the respective mass-length regressions described above. The complete lack of eggs and follicles in the spring 1996 sample suggests that food resources were inadequate to support any reproduction in that season. The rate of decline in mean testis volumes during late summer may also have been influenced by rainfall, with a sharp decline in the dry summer of 1995 and a more gradual drop during the wetter summer of 1996.

Mean clutch size was similar to that reported from California populations, and both egg production and testis enlargement appear to have peaked earlier than in California (Mayhew 1966a).

The timing of egg and follicle production in 1996 suggests that *Uma* in the Mohawk Dunes may reproduce in the fall during years of adequate summer rain, and thus may have two clutches in years with rainfall in both the winter/spring and summer seasons. This would support Mayhew's (1966a) experimentally-based speculation on their capacity for double-clutching.

The April-May peak in testis volume coincides with increased lizard activity levels, as seen on standardized transects which were walked monthly as part of our related monitoring efforts (Appendix 8).

Timing and success of recruitment
Results

We expected to see at least one cohort of young during each year of the study but the data suggest otherwise. Combining data from collected specimens (n=19) with first captures of individuals on the grid (13) and in the pitfall traps (8), we captured 15 juveniles in 1995 and 25 in 1996. We have no reference values for *Uma* body size at the time of hatching, but 9 individuals had SVL ≤ 40 mm, the smallest being 2 individuals with SVL of 35 mm. All 9 were captured in 1995.

Discussion

The timing of small juvenile captures suggests several possible scenarios: hatchlings were larger in 1996, despite the dry winter and spring; we failed to capture truly small individuals in 1996, despite a larger overall sample of juveniles; or there was not a fresh cohort which hatched in 1996.

The third explanation is supported by at least two lines of evidence. Even though there is a gap in the data due to the winter hiatus in sampling, when juvenile body length is plotted against date of capture (Fig. 3), a significant regression line ($r^2=0.50$, $p<0.0001$, N=40) links the data in what appears to be the growth curve for a single cohort which emerged between June 7 and October 1, 1995. Lack of a 1996 cohort is further supported by the complete absence of eggs from female specimens for spring of the year (Table 10).

Compared to *Uma notata* studied in California (Mayhew 1966a), the apparent season of juvenile emergence observed here began about a month earlier and continued about a month later.
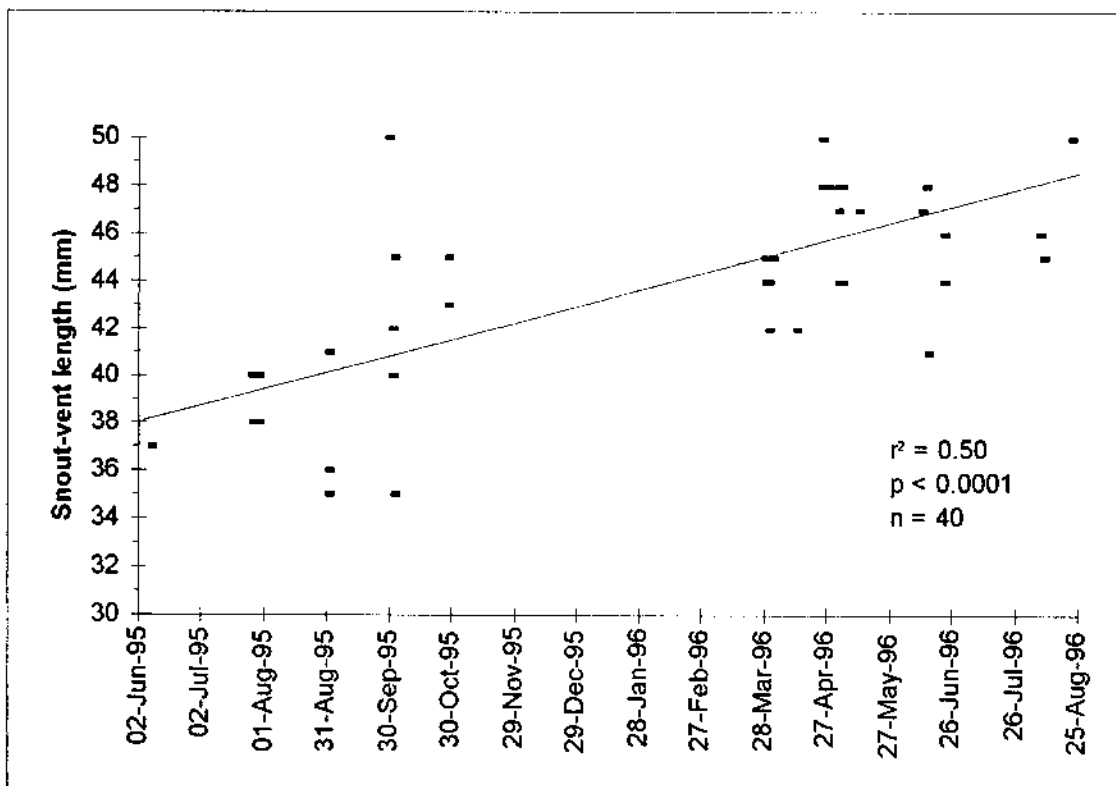
Figure 3. Size and date of captured juvenile *Uma notata*, Mohawk Dunes, 1995-96.

Survival

Results

For this analysis, there were 8 field trips which involved census efforts during April-August in 1995 and 10 during March-August in 1996.

The mark/recapture data from 1995 had a reasonably good fit ($\chi^2=15.04$, df=13, p=0.30) within the Cormack-Jolly-Seber model, while the 1996 had a relatively poor fit ($\chi^2=31.42$, df=17, p=0.02).

Survival probability estimates were high and confidence intervals narrow in both 1995 (ϕ=0.818, SE=0.062, 95%CI=0.667-0.910) and 1996 (ϕ=0.923, SE=0.027, 95%CI=0.852-0.961). Mortality rates (=1-ϕ) were therefore low in 1995 (0.182) and 1996 (0.077). Analysis by program SURGE of 4 potential survival probability models that involved terms for survival, capture probability, and (variably) time - ϕ,p, ϕ,p(t), ϕ(t),p, and ϕ(t),p(t) - found the best fit was ϕ,p(t), indicating that there was little variation in survival estimates between field trips (thus no time element) but there was substantial variation in recapture probabilities between trips.

Discussion

High survival probability would not be surprising for a species with a relatively low reproductive potential and relatively long life span. This study was too short to make definitive statements about survivorship or its corollary, mortality, but the low variance and the consistently high values suggest that these findings may be reasonably accurate for this population.

The significantly lower survival rate in 1995, when compared to 1996, may have been influenced by high juvenile mortality in late 1995 and the lack of a fresh cohort in 1996. Those factors would affect the estimates both directly, through numbers of lizards alive, and indirectly, through lower numbers of year-old lizards passing through the grid in 1996. Such transients, when first captured, would register as additions to the population, and would be counted as mortalities if they wandered away without being resighted.

The variation in recapture probabilities has been noted in the discussion of population estimates, above. In this case, it my have also been affected by pooling observations from varying numbers of census efforts into values for whole field trips, though the analysis shows no strong correlation between number of census efforts in a given trip and recapture probability for that trip.

Temperature and humidity effects
Results

We determined thermal constraints for monitoring *Uma notata* in the Mohawk Dunes by collecting body temperatures from animals captured in this study (Table 11, Fig. 4). For a sample of 150 lizards, we found a mean body temperature of 37.89°C. In addition, surface temperatures and air temperatures at 1.5 m and 5 mm high were recorded at the time of capture, though not all data were gathered for every event, resulting in differing sample sizes (Table 11, Fig. 5, 6, 7). These capture efforts generally spanned the surface-active period for the species, and thus the distribution of temperature observations should be representative of the species' surface activity.

During the 1996 field season, our direct measurements were augmented by use of frequently-recording temperature and humidity data loggers (Table 12). Due to their fixed locations, these cannot be as precise a measure of each animal's environment as those taken at the exact time and place where the animal was found, but they allowed measurement of several microenvironments simultaneously.

Table 11. Environmental and body temperatures (°C) of active *Uma notata*, Mohawk Dunes, 1995-1996. Data gathered manually at sites of captures, for marked population and collected specimens.

	Mean ± SE	Range	N
Body temperature	37.89 ± 0.23	26.9 - 43.0	150
Temperature at surface	40.00 ± 0.38	27.6 - 51.3	228
Temperature at 5mm	34.65 ± 0.26	20.7 - 42.4	224
Temperature at 1.5m	32.92 ± 0.26	18.3 - 39.6	229

Table 12. Environmental temperatures (°C) and humidities (%) associated with active *Uma notata*, Mohawk Dunes, 1996. Data gathered automatically at fixed locations at times corresponding to captures of marked population and collected specimens.

	Mean ± SE	Median	Range	N
Temperature at surface in full sun	41.31 ± 0.46	41.50	25.9 - 53.2	140
Temperature at surface in partial shade	39.54 ± 0.36	40.24	27.9 - 49.3	147
Temperature 2 cm beneath surface in full sun	38.50 ± 0.57	37.54	24.1 - 52.1	147
Temperature 2 cm beneath surface in partial shade	35.84 ± 0.47	34.39	24.8 - 47.6	147
Temperature 2 cm above surface in full shade	33.41 ± 0.34	32.86	25.5 - 41.7	147
Temperature 1.5m above surface in full shade	37.03 ± 0.31	36.74	28.4 - 49.1	145
Humidity 2 cm above surface in full shade	9.2 ± 0.62	6.6	3.1 - 39.5	145
Humidity 1.5m above surface in full shade	11.1 ± 0.65	8.9	3.7 - 39.7	147
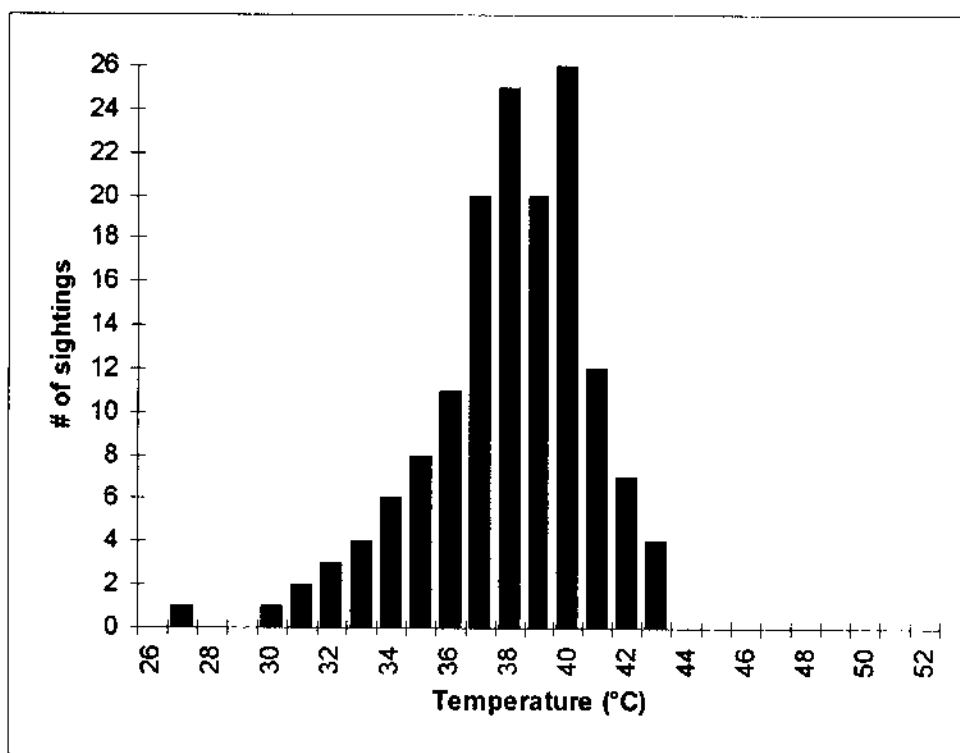
Figure 4. Body temperatures of *Uma notata*, Mohawk Dunes, 1995-96.
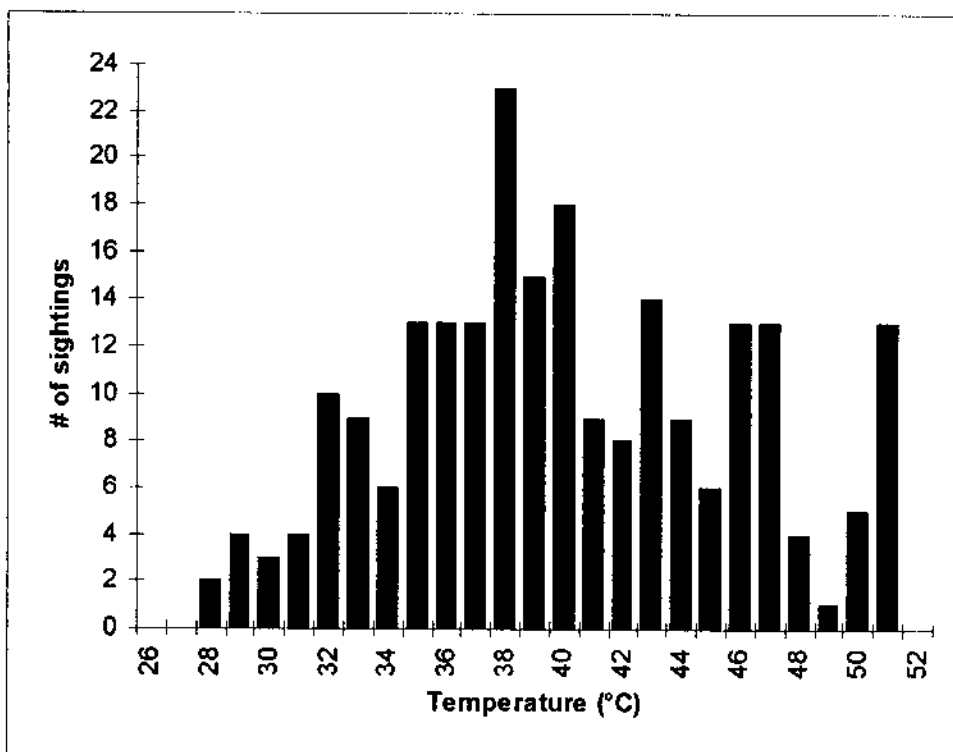
Figure 5. Surface temperatures for *Uma* sightings, Mohawk Dunes, 1995-96. Sightings shown at 51° represent those recorded as >50°.
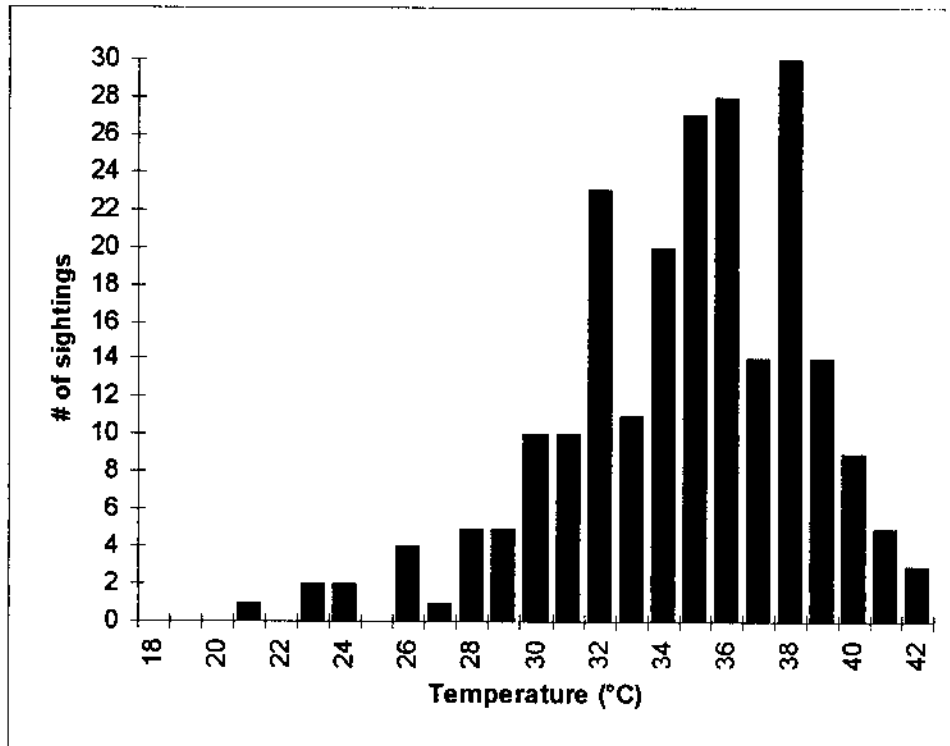
Figure 6. Air temperatures at 5 mm for *Uma* sightings, Mohawk Dunes, 1995-96.
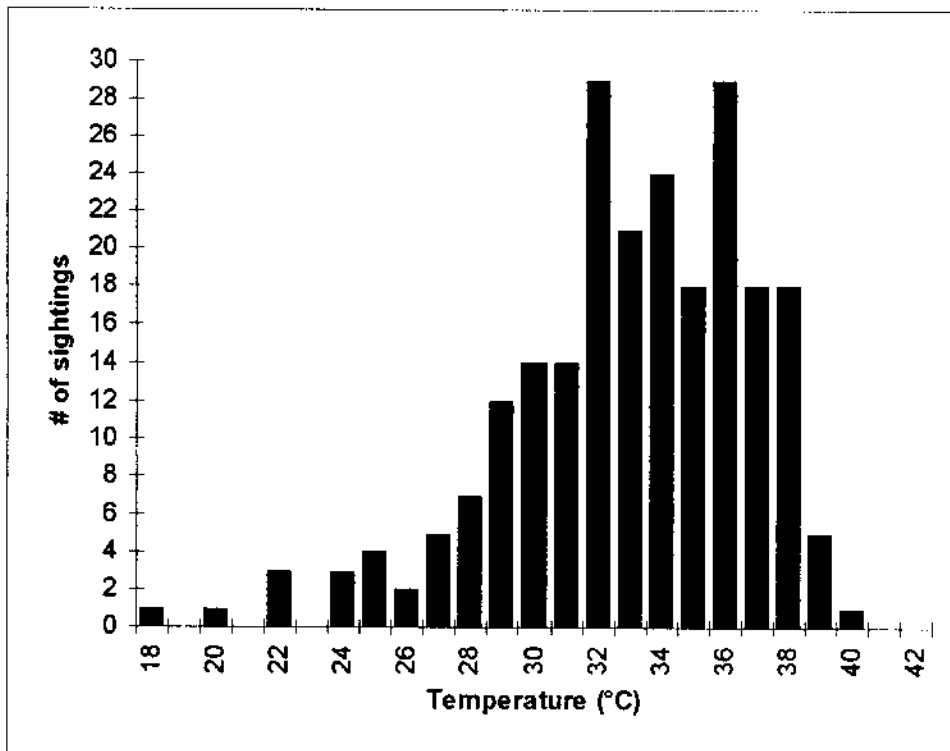
Figure 7. Air temperatures at 1.5 m for *Uma* sightings, Mohawk Dunes, 1995-96.
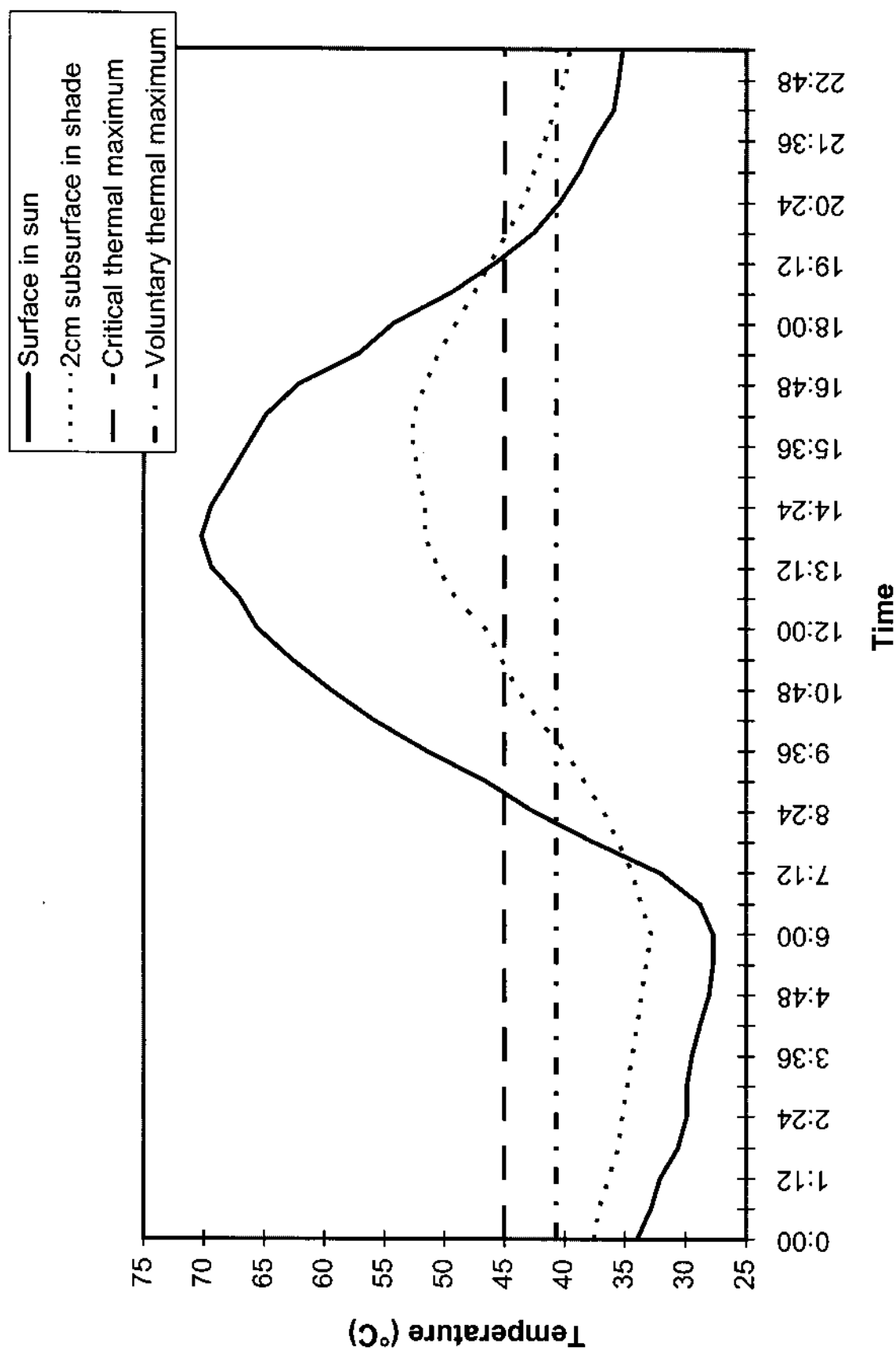
Figure 8. Soil temperatures and *Uma notata* constraints, Mohawk Dunes, 1 July 1996.
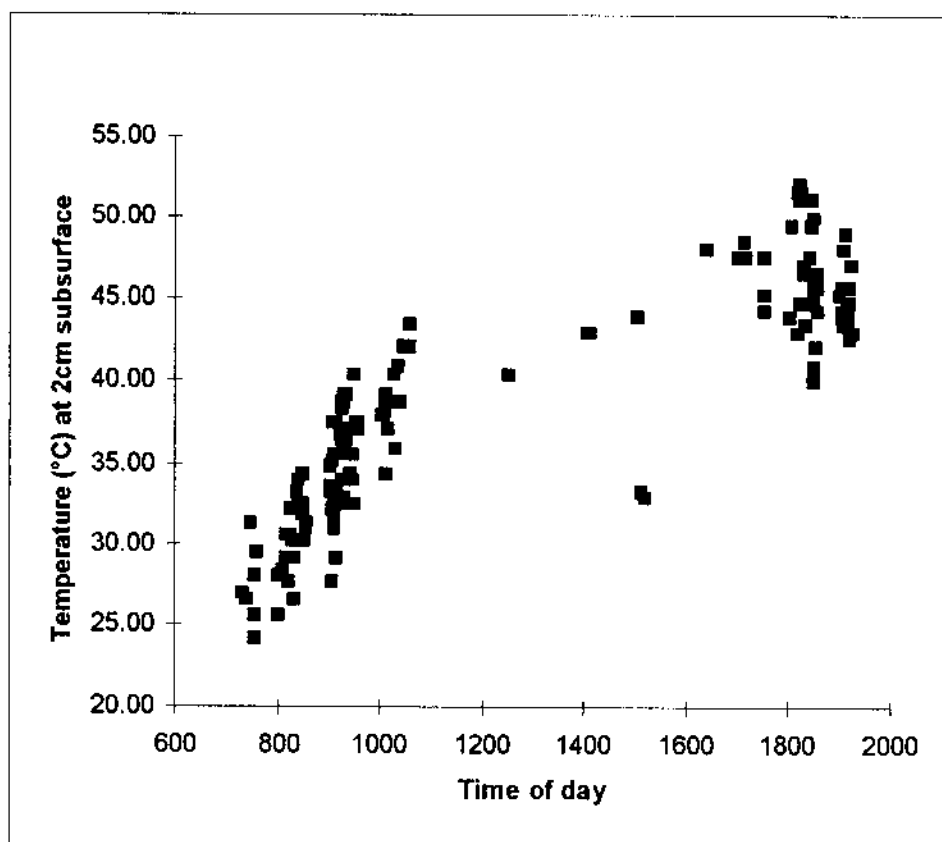
Figure 9. Soil temperatures at 2 cm depth in full sun for *Uma* sightings, Mohawk Dunes, 1996. Data gathered automatically at fixed locations at times corresponding to captures of marked population and collected specimens.
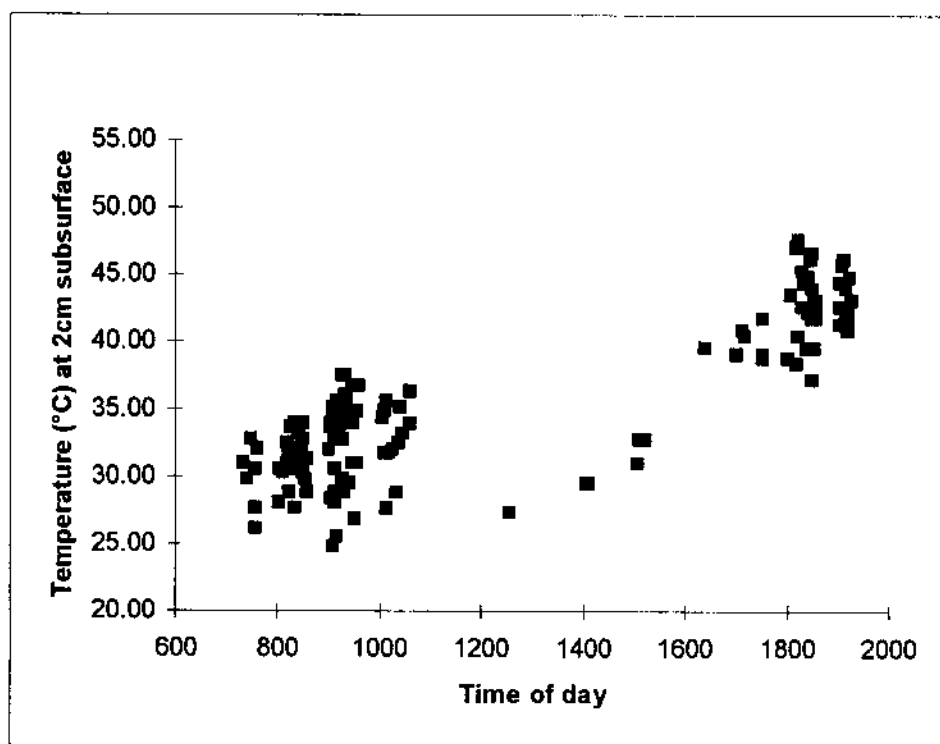
Figure 10. Soil temperatures at 2 cm depth in partial shade for *Uma* sightings, Mohawk Dunes, 1996. Data gathered automatically at fixed locations at times corresponding to captures of marked population and collected specimens.
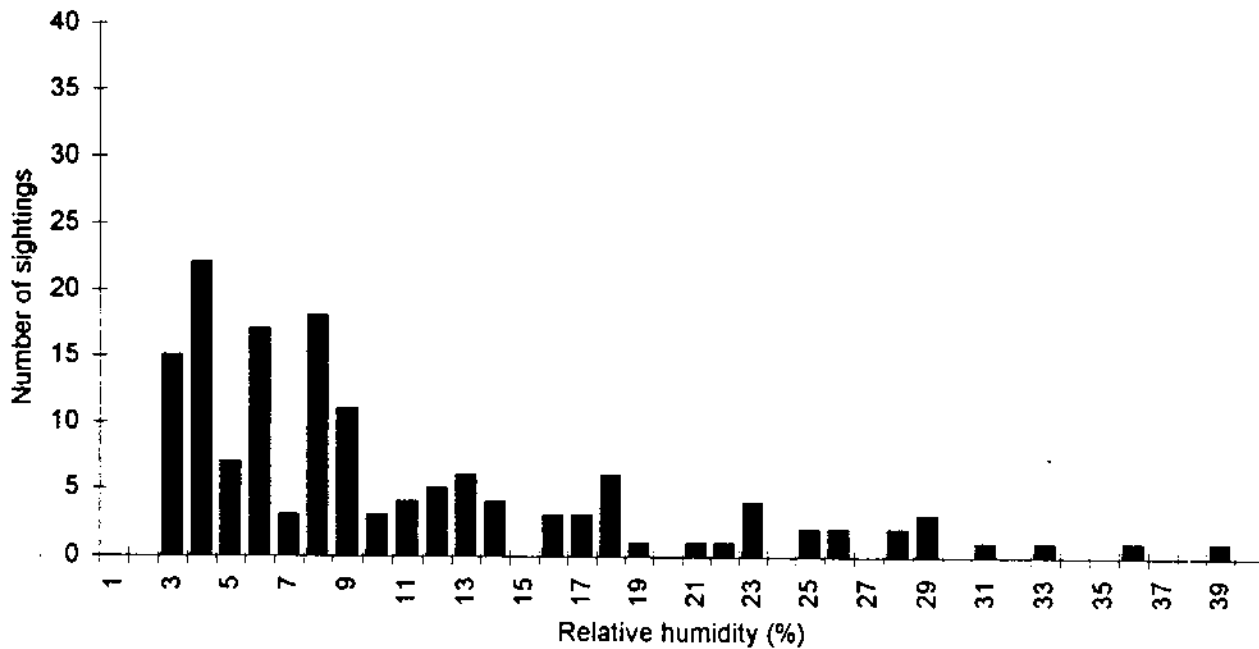
Figure 11. Humidity at 1.5 m above the surface for *Uma* sightings, Mohawk Dunes, 1996. Data gathered automatically at fixed locations at times corresponding to captures of marked population and collected specimens.
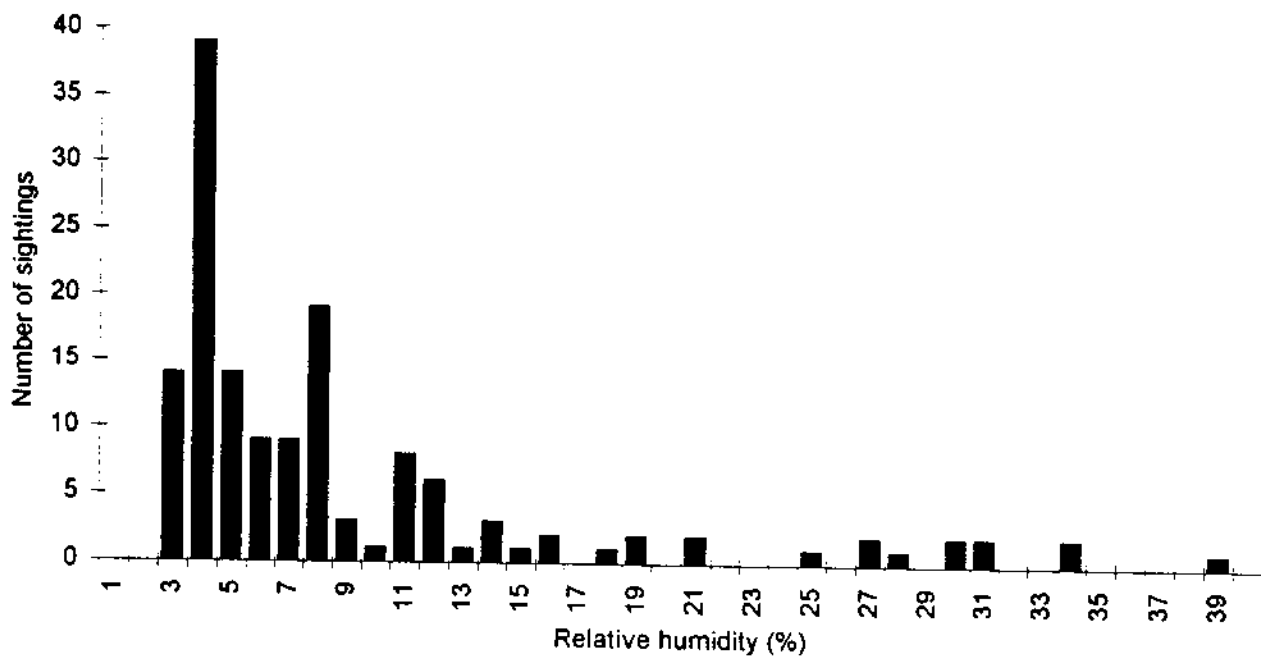
Figure 12. Humidity at 2 cm above the surface for *Uma* sightings, Mohawk Dunes, 1996. Data gathered automatically at fixed locations at times corresponding to captures of marked population and collected specimens.

Discussion
        Our mean body temperature data are similar to those found by Mayhew (1964b)
for *Uma notata* in the Algodones Dunes. For a sample of 417 lizards, he found a mean of
37.9° C with a range from 20.6° to 45.6°.
        Our surface temperature measurements averaged more than 2° higher than the
corresponding body temperatures and showed a much wider range, while air temperatures
were lower than body temperatures. These differences demonstrate the effectiveness of
the lizards' behavioral thermoregulation in achieving and maintaining their internal
conditions around some set point or preferred value.
        These surface temperatures are also significant for future study or monitoring
efforts. The 25th and 75th percentiles for our observations, 36.1° and 44.1°C, would be
reasonable boundaries for most efforts. These are slightly higher than our recommended
starting temperatures, between 35° and 42°C, for *Uma notata* monitoring transects
(Turner et al. 1997a) due to the speed with which surface temperatures rise in April or
May, our recommended monitoring season.
        Subsurface temperatures corresponding with lizard observations showed
interesting bimodal patterns (Fig. 8, 9, 10). During most morning observations of lizards,
the sand at 2 cm depth was between the voluntary minimum and maximum temperatures
for the species. Thus, the lizards observed in the morning could have easily emerged from
the sand moments before and could have comfortably dived back into the sand. At the
times of most afternoon sightings, the subsurface temperatures were above the voluntary
minimum; in many cases they were above the critical maximum, especially where the
surface was in full sun. Thus, the lizards observed then had likely not been under the sand,
and were not likely to use the sand as cover for extended periods. Indeed, for many of
those individuals, seeking refuge by shallow submersion in the sand would have meant
rapid death by overheating.
        Humidity readings near the sand surface at the times of lizard observations were
generally lower than those recorded at 1.5 m (Fig. 11, 12), as expected from the
temperature/humidity relationship; higher air temperatures produced lower relative
humidity values for the same absolute humidities. They covered a wide range but were
heavily skewed to the low end, with 74% of the 2 cm readings in the range 3-9%
humidity, and 73% of the 1.5 m readings in the range 3-13%. The absence of readings in
the 1-2% range suggests that the humidity data loggers failed to register below 3%.
        Unlike the temperature data discussed above, we were unable to identify clear
humidity cues that correlate with particular lizard behavior. Since we had few
observations of activity following the infrequent rainfalls we were unable to determine the
effect of humidity on lizard activity. Most of our lizard observations were made during
periods of low humidity. Apparently humidity is not an important activity cue for *Uma*
during most of the active season.

Home range

<u>Results and discussion</u>

For this portion of the study, we conducted 13 full surveys of the study grid in 1995 and 38 full surveys in 1996, not counting partial surveys and incidental observations. We marked 52 *Uma* on or within 20 m of the grid, collecting data from 77 observations of those lizards in 1995 and 152 observations in 1996 (location data in Appendix 2). Of these marked lizards, 11 were resighted ≥ 3 times in 1995 and 17 in 1996, allowing the mapping and measurement of polygonal home ranges for them (Fig. 13, 14). The data used here include 24 individuals total, since some were seen ≥ 3 times in both years.

The 28 individuals which were sighted ≤ 2 times on the grid are assumed to be neighbors captured at the edges of their home ranges, transients just passing through the area, or mortalities.

In this study, the maximum number of sightings for an individual lizard in a given year was 13. For those with enough (≥ 3) sightings to determine an MCP, the mean was 6.2 sightings (SE=0.6, n=28). The single-year, unadjusted home range values for all individuals with ≥ 3 sightings ranged from 8 to 1,593 m^2.

We attempted to determine whether the ranges appear to approach an asymptote at some sample size (Harris et al. 1990, Rose 1982). We took data from 5 individuals for which we have ≥ 10 sightings in a single year and assumed the calculated home range for each to be 100% of their actual home range. For the data set of each individual, we then removed a randomly-chosen sighting location and recalculated the remaining home range. This process was repeated until the data set was reduced to 4 sightings. The resulting shrunken ranges were divided by the individual's total range to give a percent of the total, and those percentages plotted against their associated number of sightings (Fig. 15). While not definitive, the graph suggests that we approached but did not quite reach an asymptote with 13 sightings, supporting use of the adjustment to an assumed asymptote of 16.

We tested for sample size bias in the data by performing a regression analysis of MCP size versus sample size and found a significant correlation (r^2=0.33, p=0.001).

After adjustment for sample size bias, the mean home range for 1995 was almost twice that calculated for 1996 (Table 13). This may be due to higher population density in 1996 (see discussion below) or to a lower proportion of adults in 1996 (Table 4). It may also be an artifact of the correction equation, since the 1995 data involved fewer observations per lizard and thus greater adjustment from the actual polygons. However, we found essentially no correlation (r^2=0.02, p=0.51) between adjusted home range size and sample size, indicating that there is no consistent bias in the adjustments. It is worth noting, however, that the 2 highest adjusted values came from MCPs formed by 3 observations each, and were thus subject to the greatest level of adjustment.

Dividing the data for analysis by size classes, we used the first body measurement of each individual for the year in question. Predictably, adjusted home range size was significantly greater for individuals with greater snout-vent lengths (r^2=0.22, p=0.02), after removal of one extreme outlier produced by the adjustment process (Table 14, Fig. 16).
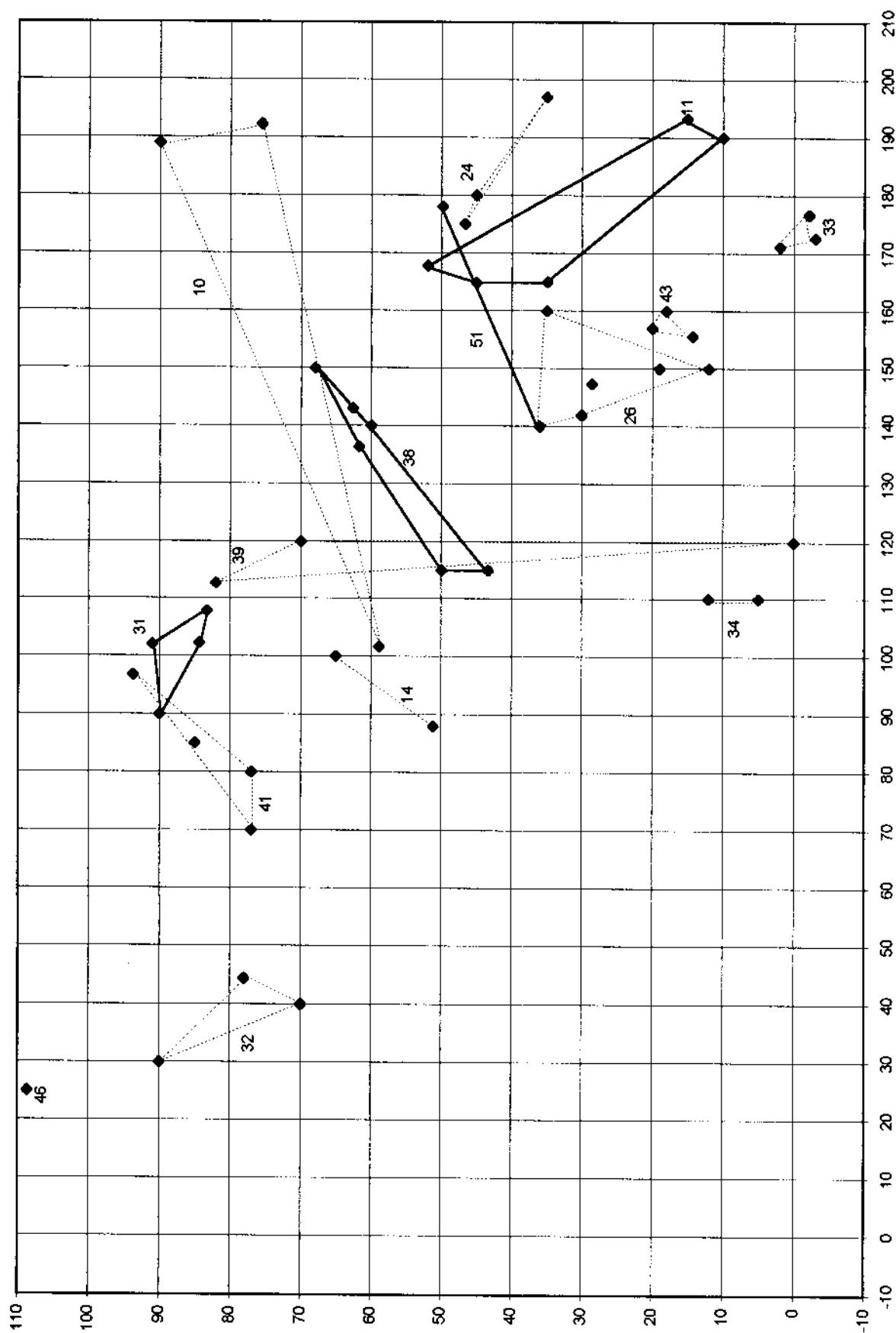
Figure 13. Minimum convex polygon home ranges for *Uma notata*, Mohawk Dunes, 1995.
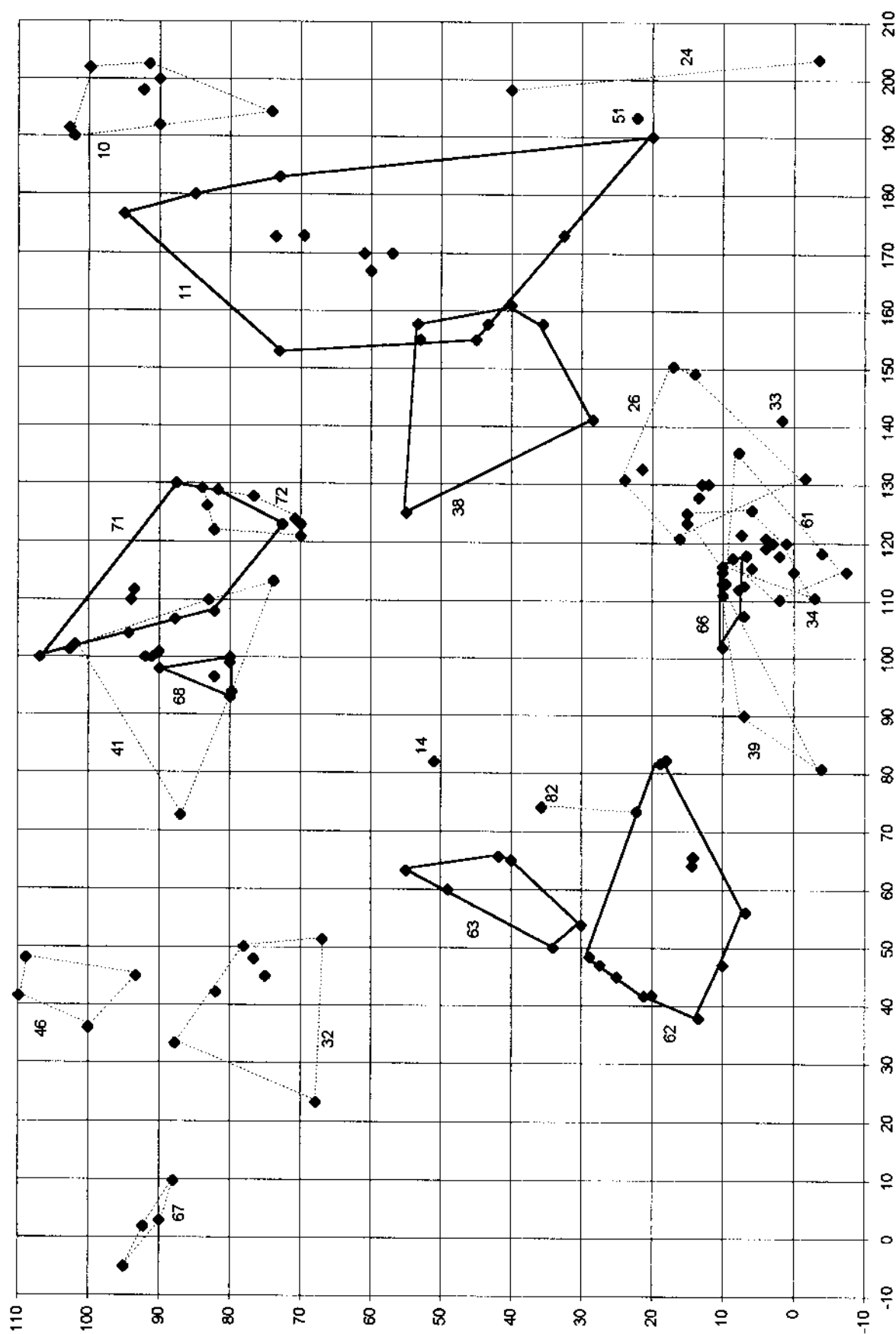
Figure 14. Minimum convex polygon home ranges for *Uma notata*, Mohawk Dunes, 1996.
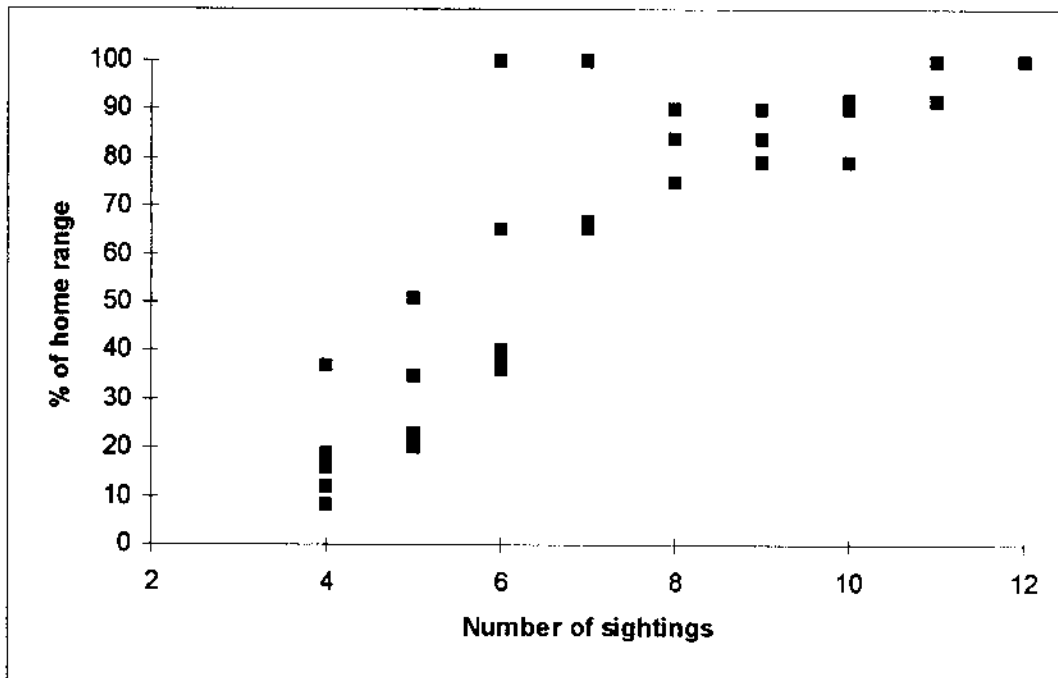
Figure 15. The relationship between number of sightings and percent of final convex polygon estimate of home range size for 5 *Uma notata* individuals, each with ≥10 sightings.

Table 13. *Uma notata* home ranges by year in the Mohawk Dunes, 1995-1996.

	1995 Minimum convex polygons	1995 Adjusted	1996 Minimum convex polygons	1996 Adjusted
Mean home range (m²)	176	1,111	326	599
Standard error (m²)	60	541	92	123
Median (m²)	85	374	202	507
Range (m²)	8 - 655	75 - 6,154	12 - 1,593	51 - 1,849
Number of lizards	11	11	17	17
Mean # observations/lizard	3.9	3.9	7.6	7.6

Table 14. *Uma notata* home ranges by sex and size class in the Mohawk Dunes.

Lizard size class	Mean MCP (m²)	Standard error	Mean adj. home range (m²)	Standard error	N (lizards)
MALE					
Adult	530	70	994	422	2
Immature	549	354	912	368	4
Juvenile	193	117	290	133	4
Combined	403	148	680	189	10
FEMALE					
Adult	228	82	1446	722	8
Immature	177	51	462	91	8
Juvenile	107	95	169	118	2
Combined	192	43	867	336	18
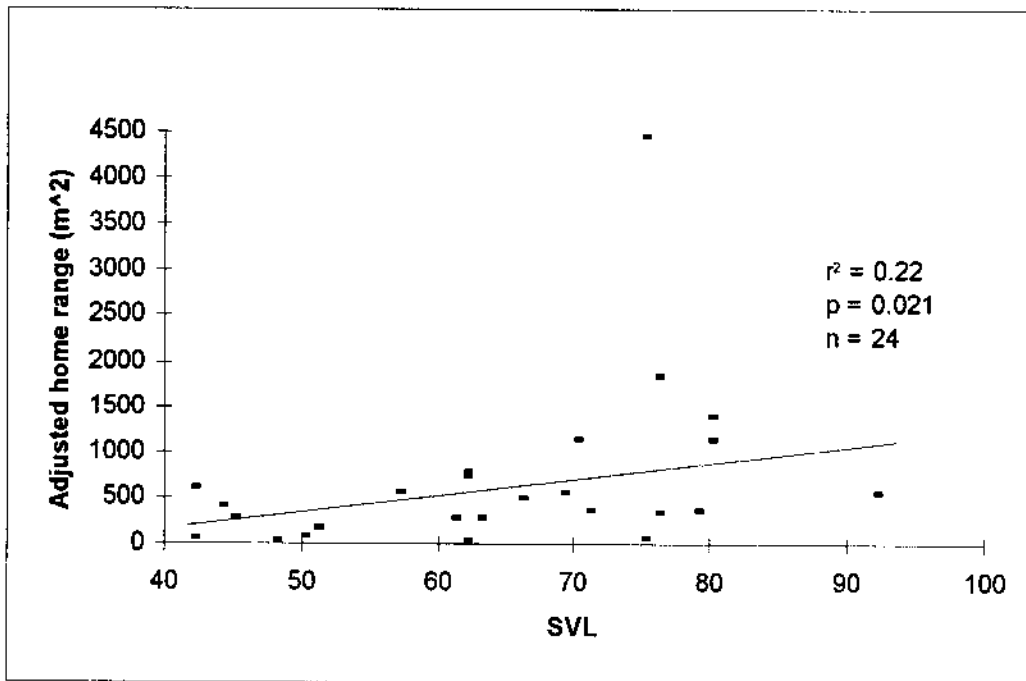
Figure 16. Home range, adjusted for sample size, and its correlation to body size. Regression analysis performed after removal of single highest outlier.

An unpublished study of another *Uma* species gives comparison values for home ranges. Muth and Fisher (1991) described MCP home ranges for 128 *Uma inornata* individuals for which there were enough sightings to reach their asymptotes (Table 15). Thus they did not need or use sample size corrections, and did not report sample sizes used.

Table 15. *Uma inornata* home range sizes (minimum convex polygons), from Muth and Fisher (1991).

Lizard size class	MALE Mean MCP (m²)	Standard error	N (lizards)	FEMALE Mean MCP (m²)	Standard error	N (lizards)
Adult	1040.3	107.5	27	389.5	37.3	39
Immature	272.6	33.2	23	176.0	37.6	15
Juvenile	66.1	17.8	10	44.2	6.3	14
Combined	583.6	73.7	60	271.3	28.8	68

In comparison to similarly-adjusted published mean values for several other lizard species found in the Mohawk Dunes, our data show *Uma notata* using larger home ranges than *Dipsosaurus dorsalis* (male 674 m², female 642 m²)and *Uta stansburiana* (males 442-701 m², females 172-240 m²)(Christian and Waldschmidt 1984).

We observed little overlap between the home ranges of adults, but found overlap to be common among juveniles and immatures, and between adults and juveniles or immatures.

While we might expect to see a certain amount of long-distance movement, especially by juveniles or immatures seeking available territories, it was interesting to note that none of the lizards marked on the grid were captured in our pitfall traps and vice

versa. The 2 closest of 4 dune crest pitfall trap arrays were 188 and 232 m from the nearest points of the grid. Similarly, of the 34 *Uma* captured in pitfall traps, none were ever caught in traps belonging to different arrays, those arrays being strung out along a dune crest at intervals of 100-250 m.

Territoriality and tail loss
Results
There was no significant difference in incidence of tail loss between the collected and marked samples (2-tailed t-test, p=0.42), so the data sets were pooled, for a combined sample of 133 females and 125 males. Overall, 45% of *Uma notata* we examined had evidence of tail loss. Combining all size classes, there was no significant difference between the sexes in the proportion of tail loss (2-tailed t-test, p=0.27). However, juvenile (33%) and immature (34%) males had greater levels of tail loss than juvenile (21%) and immature (24%) females. There was no significant difference between tail loss incidence in adult males (62%) and females (65%)(Fig. 17). Missing digits and scars from *Uma*-sized bites on tails, legs and bodies were noted in both sexes, suggesting a significant level of intraspecific combat.

Discussion
The lack of difference between male and female adult tail loss suggests several alternative explanations: 1) most tail loss is due to unsuccessful predation events; 2) there is no territorial defense behavior; 3) it is performed equally by both sexes; or 4) both sexes engage in some other form of aggression (e.g., competition for particular mates or food items). The second explanation fits the observations of Muth and Fisher (1991) but does not explain the other scars observed unless we also accept the fourth explanation. Female defense of home ranges against other females is known to occur in some species, sometimes in conjunction with male defense against males (Stamps 1977). Resolution of this question will require more direct behavioral observation than was involved in this study.

Also unclear are the implications of the greater tail loss sustained by juvenile and immature males. Prior to sexual maturity, males seem unlikely to engage in territorial defense. Muth and Fisher (1991) found no statistical differences between survivorship of *U. inornata* males and females by age, suggesting there is no difference in successful predation attempts. Our data suggest there may be some greater exposure of young males to unsuccessful predation attempts.

Another interesting question is raised by comparing these results to some published values. Luckenbach and Bury (1983) found that in natural conditions unaffected by off-road vehicles, 21% of *Uma notata* taken from the Algodones Dunes (n=239) had experienced tail loss and regeneration. Among those taken from areas of Algodones Dunes used by off-road vehicles (n=65), 60% had experienced tail loss and regeneration. Our combined data set for the Mohawk Dunes (n=258) showed 45% had experienced tail loss. While there were a few illegal off-road excursions into the area during this study, the Mohawk Dunes population was essentially unaffected by them. Higher predation levels seems a likely explanation for the relatively high level of tail loss observed.
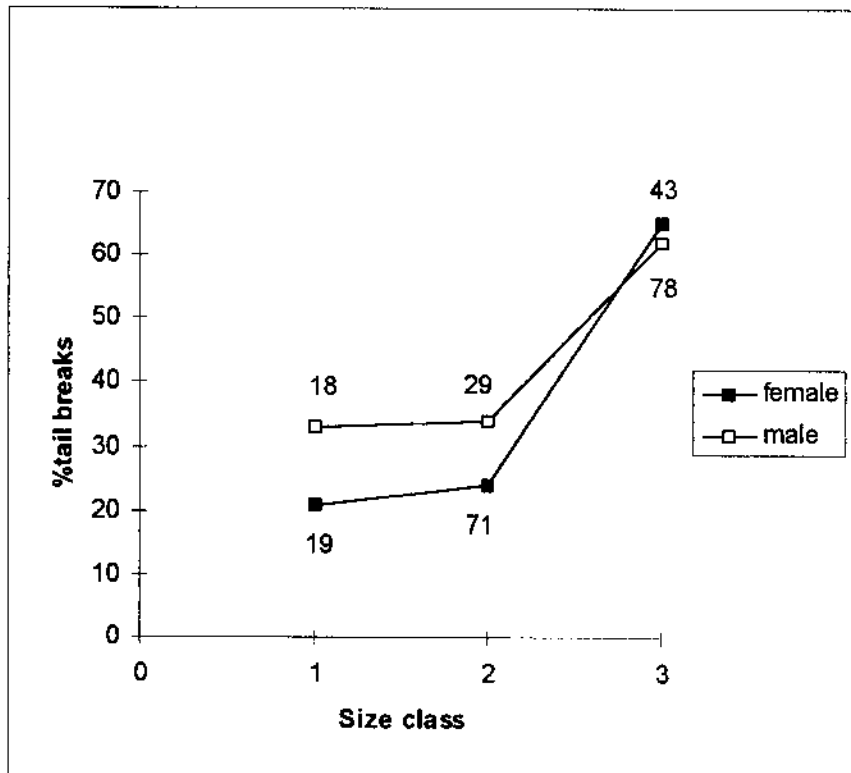
Figure 17. *Uma notata* **tail loss by size class in the Mohawk Dunes, AZ.** The same size classes were used for both sexes, with class 1 being <50 mm SVL, class 2 as 50-69 mm, and class 3 as ≥70 mm. This includes data from collected specimens and first captures of marked lizards. Sample sizes are indicated beside data points.

Selection and characteristics of escape cover

Results

Ground cover was scant in cells on the study grid, averaging 7.67%. Available cover was formed by 4 perennial plant species - *Ambrosia dumosa* (AMDU), *Ephedra trifurca* (EPTR), *Hilaria rigida* (HIRI), and *Psorothamnus emoryi* (PSEM) - along with dead woody debris (DEAD) formed primarily by the annual *Dicorea canescens*. (Table 16).

Table 16. Available ground cover (%) on 2-ha study grid, Mohawk Dunes, Arizona. Estimates taken on 10 x 10 m cells, n=200.

Cover type	Mean	Std. error	Range	Proportion (%)
AMDU	0.95	0.118	0 - 9	12.3
EPTR	2.02	0.256	0 - 24	26.3
HIRI	2.35	0.151	0 - 11	30.7
PSEM	0.87	0.102	0 - 10	11.4
DEAD	1.49	0.091	0 - 6	19.4
Total	7.67	0.279	1 - 30	100.1

Detailed measurements on vegetation in a randomly-selected 10% of the grid cells validated the estimates made on all cells. Comparing the 2 sets of cover values for the same 20 cells showed a difference in mean values of ≤0.47% for each category. Thus we used the whole-grid estimates for this analysis.

Behavioral data useful for this analysis comprise 142 observations of 35 individual lizards. In 32 cases (22.5%), lizards were found under cover (i.e., distance to cover =0), significantly greater than the availability of cover (χ^2=30.8, 1 df, p< 0.001). They ran to locations under cover in 89 cases (62.7%), again significantly different from availability (χ^2=425.6, 1 df, p< 0.001) (Fig. 18). There was a significant difference between the number found under cover and the number that stayed under cover (χ^2=92.7, 1 df, p< 0.001), i.e., most lizards ran even if they were under cover when they first felt threatened.
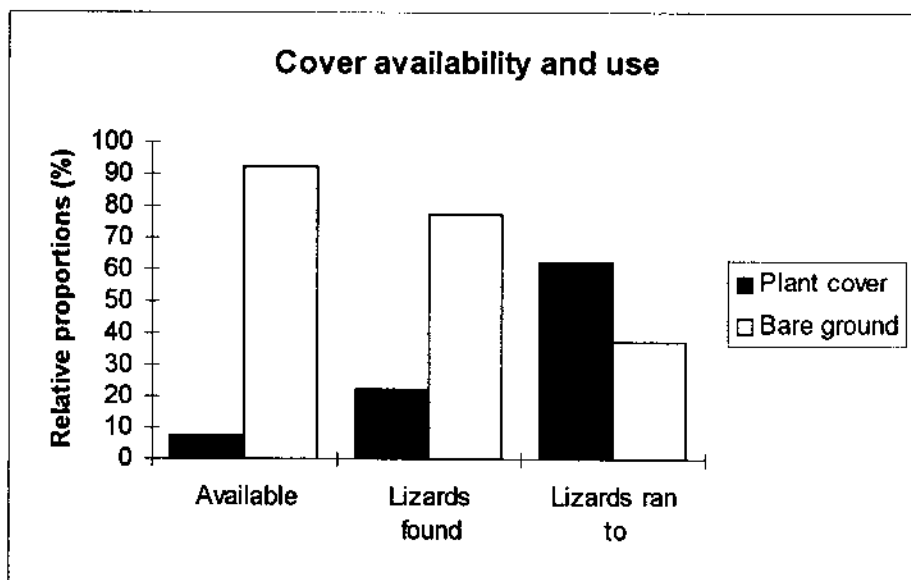
Figure 18. Relative proportions (%) of cover availability and cover use.

Lizards ran to or stayed under the closest available cover in 32.4% of the observations. Mean distance run was 5.6 m (SE=0.4, range 0-40). Mean distance to cover from where lizards were found was 1.0 m (SE=0.1, range 0-4). Mean distance to cover from where lizards stopped running was 0.6 m (SE=0.1, range 0-5). To some degree, these distances to cover are an artifact of the relatively even distribution of plants, but the difference between where lizards were found and where they stopped signifies that they usually ran close to plants even when they did not run under them.

The cover types from which lizards ran (Table 17) did not differ significantly from their proportional availability for any individual category of cover, though this may be an artifact of low sample size (n=32) and resultant wide confidence intervals.

For those cases (n=89) where lizards ran to a point under cover, their selection of cover types (Table 17) was significantly different from availability (χ^2=53.73, 4 df, p< 0.001). These figures are slightly inflated by double-counting one event in which the destination cover was a mixture of two types; that event was recorded for both types present. Lizards selected *A. dumosa* more frequently than its availability, and selected dead woody cover less frequently than its availability (Fig. 19).

Table 17. Cover types on study grid where *Uma* were found and to which they ran.
Observed values are slightly inflated by double-counting one event in which the cover was a mixture of two types; that event was recorded for both types present. Sample totals represent actual sample sizes.

Cover type	Number where found	Proportion where found (%)	Number where ran	Proportion where ran (%)
AMDU	7	21.9	29	32.6
EPTR	4	12.5	17	19.1
HIRI	8	25.0	21	23.6
PSEM	5	15.6	18	20.2
DEAD	8	25.0	5	5.6
Total	32	100.0	89	101.1

The chi-square test is sensitive to inclusion of resources that are commonly available but rarely used (Thomas and Taylor 1990), and the dead cover category appears to fit that description. Data were re-analyzed without observations in that category (revised n=84). Overall cover use was still significantly different from availability (χ^2=37.04, 3 df, p< 0.001), and *A. dumosa* still appears to have been preferentially selected. However, this analysis shows both *E. trifurca* and *H. rigida* as having been selected less than available (Fig. 20).

Results from collections

Similar data on cover use were gathered for some of the *Uma* collected during this project (Table 18). They cannot be subjected to the same use/availability analysis, since no associated availability was recorded for the widely-scattered collection localities and our available data show significant variation between Mohawk Dunes sites in total cover and relative proportions of particular cover types (Turner et al. 1997a).

Despite that limitation, this additional data set shows some interesting similarities and differences. Lizards were found under or near cover in 18 of 36 cases (50%), while they ran to cover in 30 of 31 cases (97%). For those which used cover, *A. dumosa* was the most commonly used type while *E. trifurca* assumed less importance.

Two other cover types were recorded for the collected lizards. One lizard ran to *Larrea tridentata* (LATR), a species not found on the study grid and rarely found on the dune crests used by *Uma*.

Discussion

Lizards in this study were not distributed randomly across the sand. The results support the hypothesis that *U. notata* use vegetation for escape cover, and show the species selects *A. dumosa* in a non-random fashion while avoiding *E. trifurca* and *H. rigida* to some degree.

The use of vegetation is not surprising. While *Uma* are capable of disappearing under sand in exposed locations, that trick will not be effective if a predator observes the act of burrowing. Thus, running under or behind a shrub when avoiding a predator may be a necessary adjunct to burrowing for escape. Moreover, the crypticity of a stationary *Uma* under a shrub may be sufficient to render burrowing unnecessary. Burrowing appears to be energetically costly and may hinder a lizard's ability to flee further if rediscovered, suggesting that it be used judiciously.
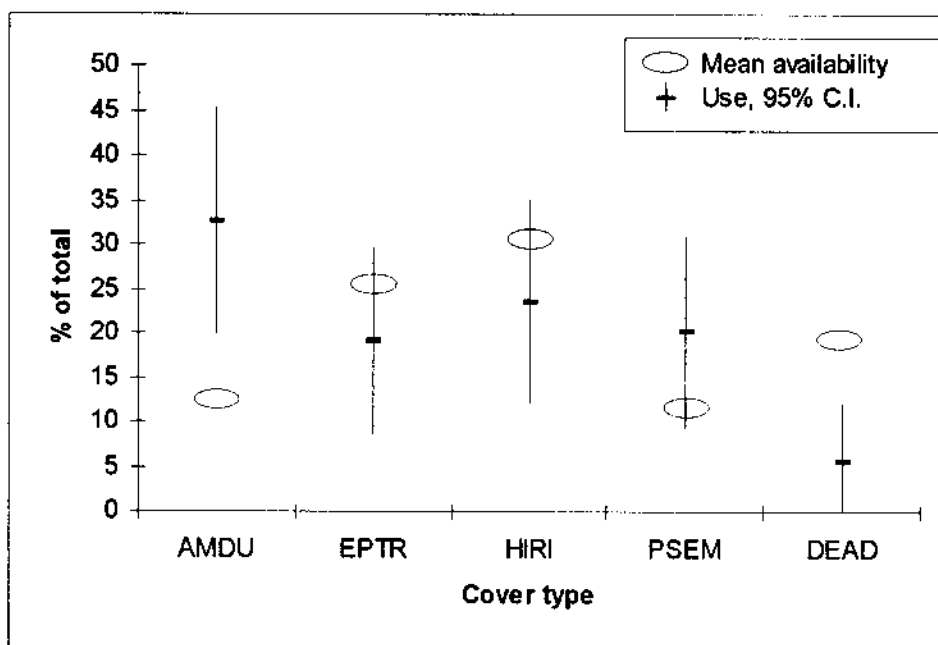
Figure 19. Proportion of cover type to which lizards ran, including all types used. Mean and 95% confidence intervals shown as lines, with proportion available shown as ellipses.
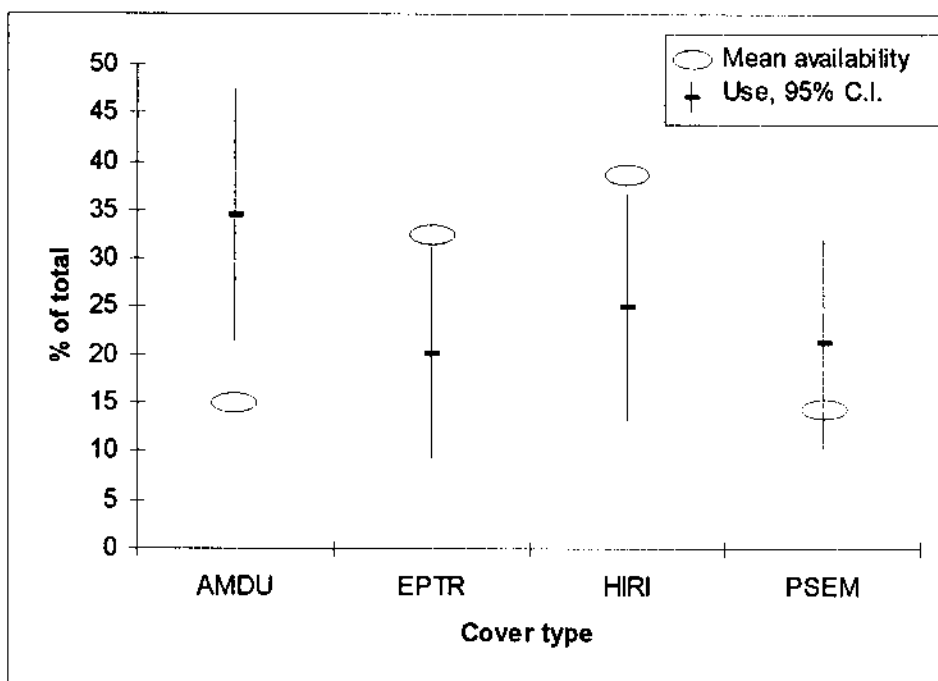

Figure 20. Proportion of cover type to which lizards ran, excluding dead woody debris. Mean and 95% confidence intervals shown as lines, with proportion available shown as ellipses.

Table 18. Cover types where collected *Uma* were found and to which they ran.

Cover type	Number where found	Proportion where found (%)	Number where ran	Proportion where ran (%)
AMDU	8	44	17	57
EPTR	0	0	4	13
HIRI	6	33	2	7
PSEM	2	11	2	7
DEAD	2	11	0	0
BURROW	0	0	4	13
LATR	0	0	1	3
Total	18	99	30	100

Similar behavior has been reported for a closely-related species, *Callisaurus draconoides* (zebra-tailed lizard). Members of this species also use sand-diving as an escape mechanism, but typically run to the far side of vegetation before burial out of a perceived predator's sight (Arnold 1995, Hasson et al. 1989).

Bulova (1994) found that the proximity *C. draconoides* would allow an approaching observer to reach before fleeing was correlated with local vegetative cover: lizards were wariest when they had the least cover available. A similar pattern has been described for the lacertid lizard *Psammodromus algirus* (Martín and López 1995).

Thermal considerations of vegetation also weigh heavily in escape behavior. Pough (1970) found that dune surface temperatures can vary by >25°C between exposed sand and the shade of a shrub, reaching maxima >60°C in full sun. He found subsurface temperatures >45°C and thereby lethal to *Uma* (Brattstrom 1965) in exposed locations at depths >5 cm, while the lizards rarely buried themselves >4 cm. Our thermal data supported these findings (Table 12, Fig. 8, 9, 10).

Different plant species provide different levels of shade and of access by larger predators, so the differential use of certain plant species may be explained by their characteristic vegetative structures. *Ambrosia dumosa* forms a dense, low, spiny crown; *Psorothamnus emoryi* forms a dense, slightly higher crown of supple stems; *Hilaria rigida* forms upright clumps that are largely impenetrable through much of their diameter; while *Ephedra trifurca* forms high, loose canopies that are largely open underneath and around the sides.

An interesting similarity was found during the most detailed ecological study to date of the flat-tailed horned lizard, *Phrynosoma mcallii* (Muth and Fisher 1992). In an area with similar levels of ground cover (6%), similar plant species composition, and a sympatric population of *Uma notata, P. mcallii* selected *Ambrosia dumosa* and *Psorothamnus emoryi* more commonly than those species were available.

An unfortunate gap in the data from the grid captures is those lizards which successfully found refuge in rodent burrows, a type of event which appears in the data from collections. Though not frequent, this was a more common event than either data set suggests. Most lizards running into burrows became functionally irretrievable, and thus were not collected or identified for use in the mark/recapture studies. The lack of these data does not invalidate the findings above, but forms an unquantified aspect of the ecological story.

Estimates of percent ground cover may have been biased by the structure of the plants. The compact oval forms of *A. dumosa* and *P. emoryi* were easier to visually judge

than the sparse branches of *E. trifurca* or jutting stalks of *P. rigida*. This may have led to overestimates of the relative availability of the latter pair. If this bias occurred, it did not likely have a significant effect on the finding that *U. notata* selectively use *A. dumosa*, given the large difference between use and estimated availability. It may, however, have contributed to the finding of avoidance of *E. trifurca*.

Lizard habitat use may be limited to a subset of what is available due to intra- or interspecific competition (Schoener 1977, Dunham 1983). Competition was not evaluated in this study for several reasons. Transects done through the *Uma* habitat in the study area showed *Uma* to be clearly the most abundant and often the only surface-active vertebrate during its activity periods (Appendix 8), suggesting interspecific interactions are rare. One published report describes intraspecific territorial competition in *Uma* under crowded captive conditions (Carpenter 1963), but the most detailed study of wild *Uma* found no evidence of territoriality (Muth and Fisher 1991).

These results provide quantitative support for published speculations that loss of vegetative cover has a significant role in observed *Uma* population declines, but we cannot infer that the particular plant species used in the Mohawk Dunes are necessary to the lizard across its range. Published accounts of the floral communities in different dunes occupied by *U. notata* (e.g., Norris 1958, Luckenbach and Bury 1983, Felger 1980) show significant variety in plant species composition. Thus, a fruitful avenue for further study may be thermal and other properties of the different plant species.

Seasonal and ontogenetic effects on diet
<u>Results</u>

We collected 157 *U. notata* useful for this part of the study, ranging in size from 35 to 102 mm SVL, with nearly equal numbers of males (76) and females (80). The total includes one of undeterminable sex, and measurements of SVL were not possible for 3 specimens, so the sample size is slightly smaller for some analyses. In addition to these, we have prey item data from one male which was collected in 1994 after accidental trap mortality.

The stomachs contained a heterogeneous mix of arthropod and plant items, representing at least 65 taxa of arthropods from 39 families, along with at least 13 plant species in 7 families (Appendix 4). Plant material was found in 74% of the lizards, comprised 49% of the total diet volume and 23% of the total number of prey items.

The most frequent and most numerous prey types were ants (Formicidae), occurring in 96% of stomachs, leguminous seeds and flower heads (Fabaceae) in 50%, and darkling beetles (Tenebrionidae) in 37% (Table 19). Other common items included spiders (Araneae) and sand roaches (Polyphagidae).

Volumetric analysis showed leguminous seeds and flower heads comprised 29% of the total diet volume, followed in relative volume proportions by ants (20%), grasshoppers (Acrididae) (8%), composite seeds and leaves (Asteraceae)(8%), and sand roaches (5%). All the beetles (Coleoptera) together comprised almost 9% of the total diet volume (Table 19).

Other things found in the stomachs include *Uma* skin, presumably their own shed skin eaten deliberately, occurring in 4% of stomachs (disarticulation of the skin rendered it impossible to measure reasonably in most cases, so no volume estimates are provided).

Lizard scat was found in 2 stomachs (1%), suggesting an avenue for transmission of parasitic nematodes which occurred in 57% of stomachs. Small stones appeared in 13% of stomachs. We also found a large (250 mm³), sticky mass of spider web in 1 stomach.

The 1994 specimen yielded the only representative of the mustard family (Brassicaceae).

An additional 4 *Uma notata* were collected from the Yuma Dunes for comparative purposes. Besides a few of the common species, their stomachs yielded 5 more taxa of prey not found in the Mohawk specimens (Appendix 5).

Analysis of the volumetric proportions of arthropod and plant material showed several trends. Males showed a significant ontogenetic shift in diet composition (r^2=0.30, p<0.0001, n=75), with small specimens having consumed primarily arthropods while larger lizards contained increasing proportions of plant material with increasing body size, up to an even split for adults (Fig. 21). Females showed a slight but not significant trend in the same direction (r^2=0.04, p=0.09, n=78), eating primarily arthropod material through all size classes (Fig. 21). Adult females had significantly different diets from adult males (2-tailed t test, p=0.008), but the diets of juvenile and immature (combined) females and males were not significantly different (2-tailed t test, p=0.51)(Table 20).

Table 20. Mean proportions of arthropod material volumes to total stomach content volumes.

	Juvenile proportions	N	Immature proportions	N	Adult proportions	N
Male	0.89	4	0.83	25	0.50	46
Female	0.91	13	0.76	39	0.74	25

All size and sex classes showed a significant seasonal dietary shift in 1995, with progressively smaller proportions of plant material as the warm season progressed (Fig. 22, 23).

The specimens from 1996 were not consistent in their seasonal trends. Adult females had a significant trend of progressively smaller proportions of plant material as the warm season progressed, while smaller females and adult males had similar but not significant trends. Juvenile and immature male specimens, however, had a significant trend of increasing proportions of plant materials as the season progressed.

To test for confoundment of the seasonal and ontogenetic effects, we re-analyzed the data for each sex in each year, and found the same significant ontogenetic shift in males and its lack in females.

Discussion

As noted above, the Mohawk Dunes experienced extremes of rainfall during the course of this study (Fig. 1). Thus, food availability was affected in 1995 by a wet spring and dry summer, while 1996 had a dry spring and a wet summer.

Table 19. **Composition of the diet of *Uma notata* from the Mohawk Dunes, AZ, 1995-96.** Total sample N=157. Frequency is the number of lizards containing a particular prey type. Number is the number of prey items. Values which round to <0.01 are shown as 0.00.

	Frequency	Number	Number (%)	Volume (mm^3)	Volume (%)
ARACHNIDA					
Acarina	12	16	0.41	5.13	0.01
Araneae (unid.)	38	45	1.15	283.61	0.74
Lycosidae	1	1	0.03	113.39	0.30
Salticidae	10	12	0.31	31.90	0.08
Pholcidae	1	1	0.03	0.24	0.00
Xytiscidae	1	1	0.03	0.71	0.00
Opiliones	3	16	0.41	10.64	0.03
Phalangidae	2	2	0.05	1.58	0.00
Scorpiones					
Vaejovidae	5	6	0.15	90.53	0.24
INSECTA					
Apterygota					
Thysanura	1	1	0.03	0.00	0.00
Pterygota (unid.)	2	3	0.08	43.58	0.08
Blattodea					
Polyphagidae	37	48	1.22	2,068.94	5.40
Coleoptera (unid.)	19	24	0.61	136.12	0.36
Anobiidae	4	6	0.15	10.94	0.03
Bruchidae	1	1	0.03	26.42	0.07
Buprestidae	8	11	0.28	310.77	0.81
Cerambycidae	1	1	0.03	152.78	0.40
Coccinellidae	9	11	0.28	336.83	0.88
Curculionidae	3	3	0.08	117.72	0.31
Scarabaeidae	16	18	0.46	622.66	1.62
Staphylinidae	1	1	0.03	156.19	0.41
Tenebrionidae	58	132	3.36	1,518.36	3.96
Diptera (unid.)	22	32	0.81	521.42	1.36
Asilidae	3	4	0.10	151.12	0.39
Hemiptera (unid.)	1	1	0.03	1.17	0.00
Homoptera (unid.)	1	1	0.03	0.63	0.00
Aphididae	11	37	0.94	25.40	0.07
Cicadellidae	6	11	0.28	44.82	0.12
Membracidae	3	5	0.13	8.85	0.02
Tingidae	1	7	0.18	2.55	0.01
Heteroptera					
Cydnidae	4	5	0.13	78.93	0.21
Lygaeidae	21	38	0.97	115.45	0.30
Miridae	2	2	0.05	13.70	0.04
Pentatomidae	1	1	0.03	131.52	0.34

	Frequency	Number	Number (%)	Volume (mm^3)	Volume (%)
Hymenoptera (unid.)	16	22	0.56	599.28	1.56
Anthophoridae	1	1	0.03	118.85	0.31
Formicidae	151	2,410	61.37	7,612.46	19.86
Mutillidae	3	3	0.08	17.41	0.05
Tiphiidae	7	7	0.18	5.76	0.02
Isoptera	3	16	0.41	30.49	0.08
Lepidoptera	15	23	0.59	141.22	0.37
Mantodea					
Mantidae	5	5	0.13	327.69	0.85
Neuroptera					
Myrmeleontidae	14	14	0.36	232.56	0.61
Orthoptera (unid.)	1	1	0.03	27.92	0.07
Acrididae	19	25	0.64	3,215.79	8.39
Gryllacrididae	5	5	0.13	109.65	0.29
ANGIOSPERMA					
Dicotyledoneae (unid.)	29	84	2.14	1,470.11	3.84
Asteraceae	22	88	2.24	3,061.91	7.99
Boraginaceae	17	102	2.60	1,320.88	3.45
Brassicaceae*	1	1	0.03	5.98	0.02
Fabaceae	78	563	14.33	11,269.51	29.40
Loasaceae	2	2	0.05	6.28	0.02
Nyctaginaceae	2	24	0.61	1,215.55	3.17
Monocotyledoneae					
Poaceae	6	27	0.69	407.50	1.06
TOTALS		3,927	100.00	38,332.64	100.00

* Represented by a single seed found in the accidental specimen taken in 1994.

Figure 21. Ontogenetic effects on proportion of arthropod material volumes to total volumes in *Uma notata*, Mohawk Dunes, AZ, 1995-96. Vertical lines indicate size at sexual maturity for each sex.
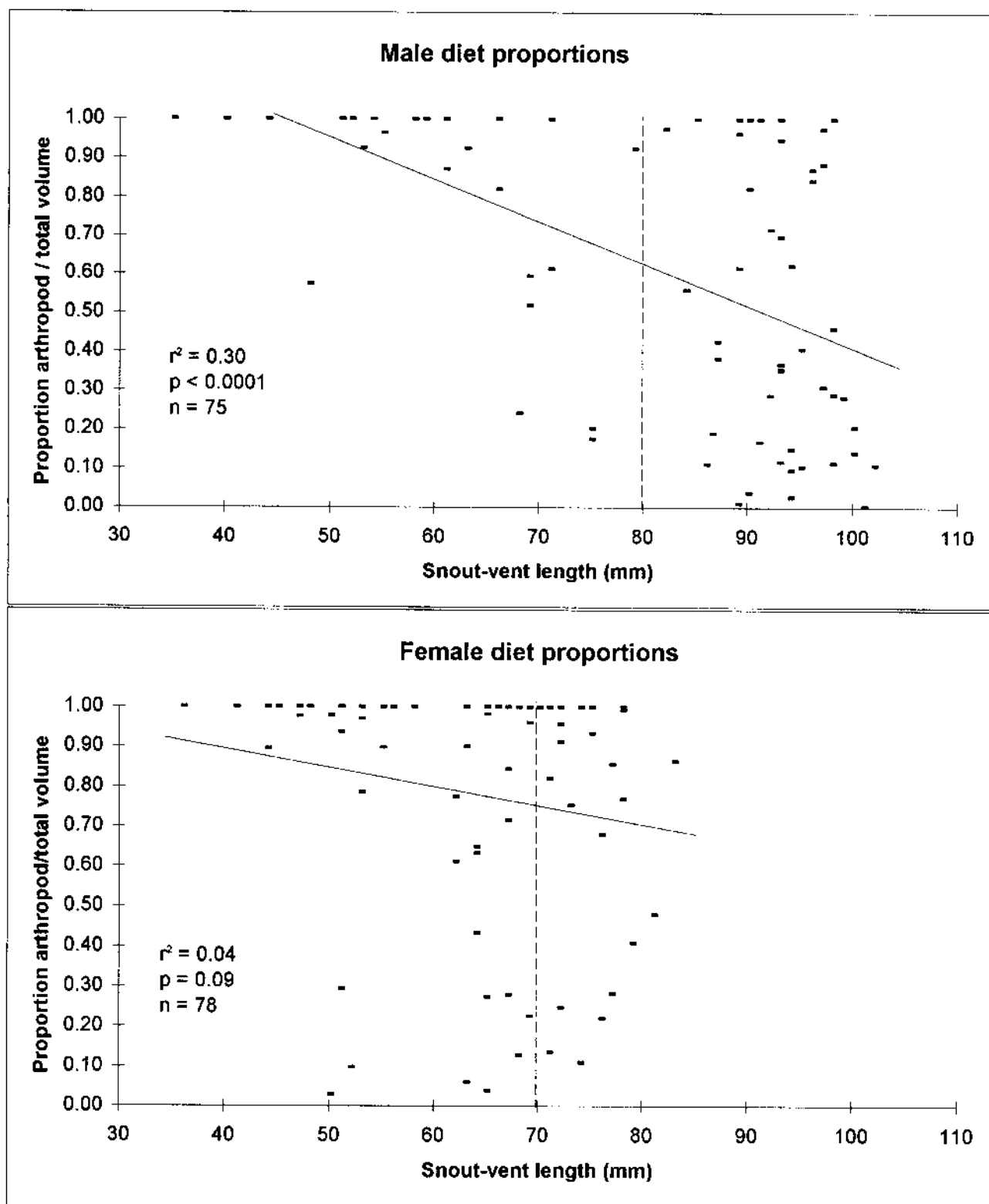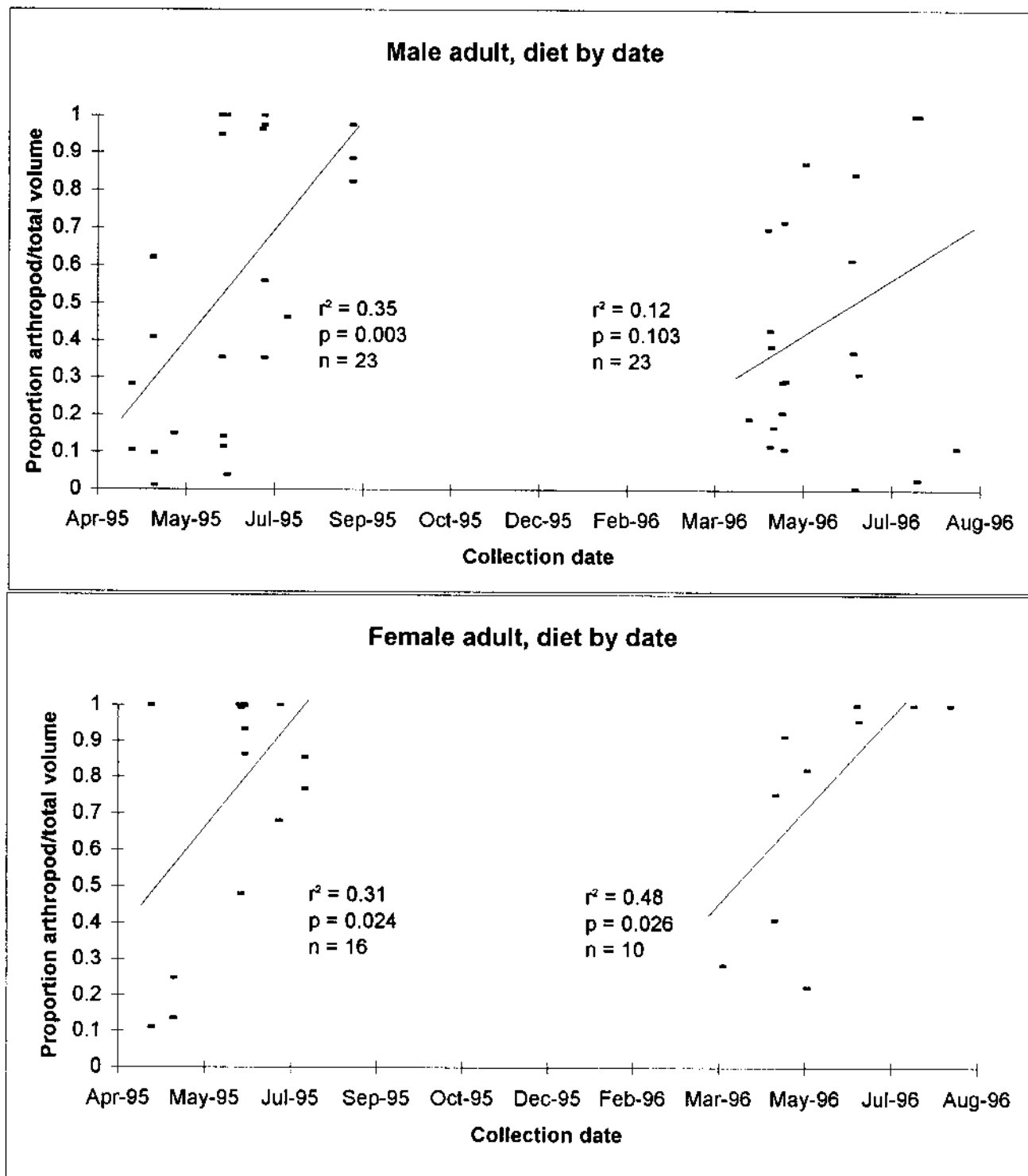
Figure 22. Seasonal effects on proportion of arthropod material volumes to total volumes in adult *Uma notata*, Mohawk Dunes, AZ, 1995-96.
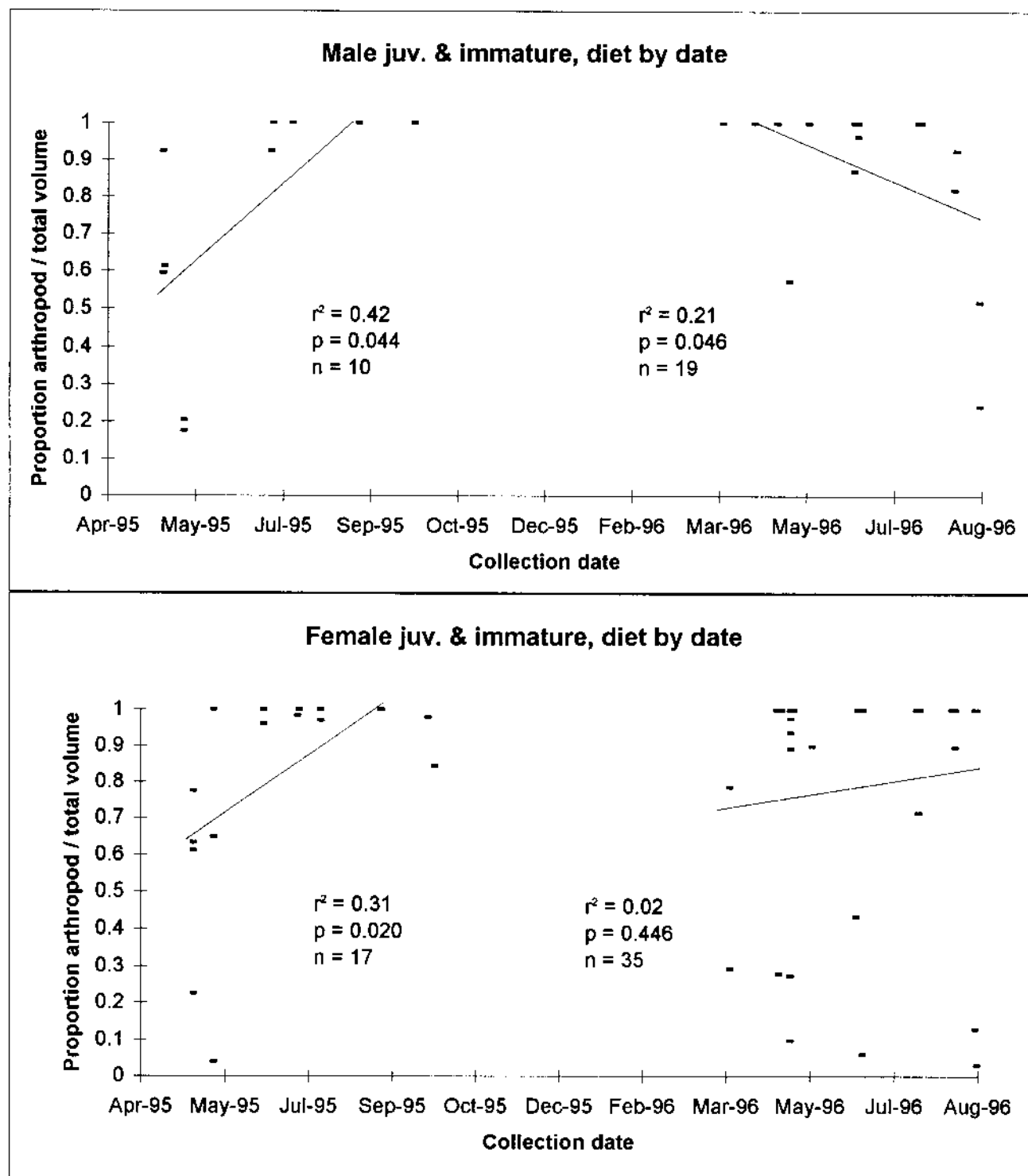
Figure 23. Seasonal effects on proportion of arthropod material volumes to total volumes in juvenile and immature (combined) *Uma notata*, **Mohawk Dunes, AZ, 1995-96.**

Seasonal rainfall patterns seem to have affected the diet of *U. notata*. Rainfall clearly affects the presence and abundance of annual plants and the condition of perennials, and these conditions may affect the availability, palatability, or physiological utility of plants for the lizards. Arthropod presence and abundance may also be affected, but it appears that enough arthropods were available to constitute an adequate diet. Ants, in particular, were a consistent presence on the dunes and in the lizards.

This study did not attempt to determine selection or preference, as food availability was neither measured nor controlled. However, the data suggest that these lizards got the bulk of their diet from just a handful of prey taxa.

Given the predominance of ants in the diet, Mayhew's (1966a) opinion that *Uma* eat primarily "insects that live close to the sand surface" appears accurate. It is worth noting, however, that arboreal arthropods (e.g., flies, wasps, and jumping spiders) were relatively common diet items.

It is possible that some of the diet items were consumed by mistake. Some arboreal invertebrates, such as aphids and tiny larvae, were probably ingested incidental to bites of leaves or flowers. Consumption of small round stones, with sizes similar to small beetles, was common, perhaps the result of misidentification or of incidental ingestion during prey capture (though such stones were rare in the sand of dune crests).

We considered but ultimately rejected the use of dry or wet weights for comparing the importance of various diet items due to the substantial and quite variable amount of sand found in the stomachs, inextricably mixed with the food. This was likely the result of sand consumed on and along with prey, in addition to that which gets entrained in mucus and passed through the gut during normal subsurface respiration (Stebbins 1943).

Annual activity cycles
Results

Despite the effects of significant variations in environmental conditions, we were able to identify several annual activity cycles of *Uma notata* in the Mohawk Dunes during the course of this and related studies. Based on testicular volume, it appears that the primary mating season was April-May and the peak in oviposition was in May. Numbers of *Uma* seen on established transects also peaked in April-May, likely due to behavior related to mating and the greater dietary needs of gravid females. Hatchlings appeared in June-August. The diet of adult *Uma* relied more on plant material in the spring and more on arthropods in fall, while those of juvenile and immature *Uma* were inconsistent between years.

We were unsuccessful in clarifying the season of hibernation. We found surface-active *Uma* as late as December 31 and as early as March 4. We observed them active when the surface temperature was 25.9-53.2°C, and our temperature data loggers frequently recorded surface temperatures above that minimum during every month of winter 1996-1997. Thus, we suspect that we would have found them in January and February had we looked during those months. We were therefore unable to identify the onset and conclusion of hibernation, or even if there is a clearly-defined and continuous hibernation period.

Summary and conclusions

Rainfall patterns during this study provided sharply contrasting conditions, as 1995 had a wet winter/spring and dry summer while 1996 had a dry winter/spring and relatively wet summer.

We found *Uma notata* to be abundant in the Mohawk Dunes, with population densities in good habitat of 15-17/ha. Their springtime physical condition, as indicated by mass/length regressions, varied according to weather conditions, with lizards measuring significantly fatter in 1995 than in 1996.

Their physical condition appears to have affected reproduction. Male reproductive readiness, as shown by testis volumes, peaked in April and May. It declined to relatively low levels by August, though that decline was less pronounced in 1996, perhaps as a result of the summer rains in July and August. Female egg production peaked in May during 1995 but did not occur in spring 1996. Limited egg production in August-September 1996 suggests the possibility of two reproductive seasons during years with both winter and summer rainfall. The 1995 hatchling cohort emerged during June-October, but we detected no 1996 cohort.

Survival rate estimates were high in both 1995 (0.818) and 1996 (0.923).

Thermal measurements at the time of *Uma notata* observations showed a mean surface temperature of 40.0°C. Mean body temperature of captured *Uma* was 37.9°.

Humidity measurements at 2 cm above the surface at the time of observations showed a median of 6.6%, but did not indicate any meaningful humidity cues for lizard behavior.

Minimum convex polygon estimates of home ranges were 530 m² for adult males and 228 m² for adult females. When adjusted for a sample size bias, these estimates were 994 and 1446 m², respectively. We observed little overlap between adult home ranges.

Overall, 45% of *Uma notata* we examined had evidence of tail loss, suggesting relatively high levels of attempted predation.

Uma notata actively used perennial plants as escape cover, preferentially selecting *Ambrosia dumosa* while using *Ephedra trifurca* and *Hilaria rigida* less than they were available.

We also found significant use of plant materials in *Uma notata* diet, comprising 49% of total diet volume and 23% of total prey items. Young lizards ate primarily insects, adding progressively greater proportions of plant items with increasing body size, especially among males. For most size classes there were seasonal shifts, with progressively smaller proportions of plant material as the warm season progressed. Overall, their diet included 65 taxa of arthropods from 39 families, along with 13 plant species in 7 families.

Management recommendations

Results of this study show that *Uma notata* use dune vegetation for food (both directly and through invertebrates) for thermoregulation, and for escape cover. These findings support previous studies which found correlations between declines in *Uma* population density and loss of dune vegetation due to off-road vehicle use.

Our primary recommendation, therefore, is that dunes occupied by *Uma notata* or its congeners be protected from off-road vehicle use. The three major Arizona populations of *U. notata* are officially closed to recreational vehicular use, but their protection varies functionally. The Pinta Sands and Yuma Dunes populations receive almost no vehicular use, due to physical isolation and agency restrictions. Occasional off-road activities by the Border Patrol are likely the major exception.

The Mohawk Dunes, while subject to vehicle closures by both the military and the Bureau of Land Management, is easily accessible and rarely patrolled, resulting in a low but noticeable level of trespass vehicular use, especially at its northern end. Some form of monitoring for such use would allow determination of any growth of this problem. A possible avenue would be the addition of dune surveys to the existing overflights done for Sonoran pronghorn or desert bighorn. Higher levels of ground patrol by BLM or AGFD agents might also serve as a deterrent.

We support continued military management of the Yuma and Mohawk Dunes in preference to a return to BLM multiple-use management, since the military presence has had very little negative impact while preventing the civilian damage documented in parts of the Algodones Dunes.

The Bouse Dunes population of *U. scoparia* is of particular concern due to heavy recreational off-road vehicle use in the area. While a small part of their habitat is Congressionally designated wilderness, the remainder has little or no protective status.

If there is reason for concern about any of the *Uma* populations, we recommend use of the monitoring protocols and baseline data presented in our Mohawk Dunes monitoring plan (Turner et al. 1997a).

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Appendix 1. Environmental data instruments: specifications and placement.

Surface temperature was recorded for a majority of observations by use of a shaded mercury-bulb thermometer (Miller & Weber cloacal, 0 to 50°C); the remainder were determined later by reference to records of electronic data loggers.

All data loggers were purchased from Onset Computer Corporation, P.O. Box 3450, Pocasset, MA 02559-3450. Model specifications were:

HoboTemp with internal sensor, -39 to 75°C (HTI)
HoboTemp with external sensor (thermistor), -39 to 123°C (HTEA)
StowAway with external sensor (thermistor), -39 to 123°C (XTI)
Hobo Relative Humidity, 5 to 95% non-condensing (HRH)

Data loggers were distributed in the following arrangement:

Instrument shelter	1.5 m above surface	HTI and HRH
Under pitfall shade	5 cm above surface	HTI and HRH
Full sun	surface	HTEA
	2 cm subsurface	HTI
Shade	surface	XTI
	2c m subsurface	HTI

Instrument shelter data loggers were attached to a board in the center of a white, wooden-slatted, box-type shelter (Forestry Suppliers #89134).

The pitfall shade consisted of a square of 1/4-inch-thick plywood, 16 by 16 inches, mounted on 2.5-inch-high wooden legs. Data loggers were attached to the center underside of the square using metal plumber's strapping.

Data loggers with external sensors were contained within sealed Lexan jars. The jars were buried in sand with 1-foot cables running to external sensors placed so as to barely protrude above the surface. The surface sensor in full sun was covered by a cap of aluminum foil to minimize radiant heat gain. The other surface sensor was under the deepest shade of a large *Psorothamnus emoryi* clump.

Subsurface data loggers were sealed in tight-fitting plastic Whirlpak bags with all excess air removed to minimize thermal buffering. They were buried under 13 mm of sand so as to place their internal sensors at 2 cm below sand surface.

Appendix 2. Sighting locality data used for home range analysis.

Uma ID	Date	X	Y
10	28-Apr-95	189	90
	08-Jun-95	102	59
	25-Jul-95	192	76
	11-May-96	194	74
	14-May-96	203	91
	02-Jun-96	190	102
	10-Jun-96	191	103
	11-Jun-96	200	90
	12-Jun-96	200	90
	21-Jun-96	202	100
	23-Jun-96	192	90
	23-Jun-96	198	92
11	28-Apr-95	190	10
	12-May-95	193	15
	06-Jun-95	165	45
	08-Jun-95	165	35
	21-Jun-95	168	52
	11-May-96	190	20
	12-May-96	173	33
	13-May-96	173	74
	14-May-96	173	70
	31-May-96	177	95
	01-Jun-96	170	61
	02-Jun-96	180	85
	10-Jun-96	183	73
	12-Jun-96	153	73
	22-Jun-96	170	57
	23-Jun-96	167	60
	21-Aug-96	155	53
	22-Aug-96	155	45
14	25-May-95	100	65
	22-Jun-95	88	51
	24-Apr-96	82	51
24	12-May-95	180	45
	08-Jun-95	197	35
	21-Jun-95	175	47
	12-May-96	198	40
	06-Aug-96	204	-4

Uma ID	Date	X	Y
26	13-May-95	150	19
	14-May-95	150	12
	06-Jun-95	142	30
	08-Jun-95	147	29
	25-Jul-95	140	36
	01-Oct-95	160	35
	13-Apr-96	130	12
	26-Apr-96	123	15
	26-Apr-96	131	-2
	12-May-96	121	16
	31-May-96	130	13
	01-Jun-96	133	21
	12-Jun-96	149	14
	13-Jun-96	150	17
	21-Jun-96	128	13
	24-Jun-96	131	24
31	13-May-95	102	91
	08-Jun-95	108	83
	22-Jun-95	90	90
	22-Jun-95	102	84
32	22-Jun-95	40	70
	11-Jul-95	44	78
	30-Sep-95	30	90
	24-Apr-96	45	75
	12-May-96	51	67
	31-May-96	50	78
	21-Jun-96	48	77
	22-Jun-96	23	68
	23-Jun-96	42	82
	21-Aug-96	33	88
33	14-May-95	173	-3
	25-May-95	177	-2
	27-Oct-95	171	2
	13-Apr-96	141	2
34	14-May-95	110	5
	21-Jun-95	110	12
	13-Apr-96	125	15
	26-Apr-96	126	6
	26-Apr-96	121	7
	12-May-96	120	3
	02-Jun-96	120	1
	22-Jun-96	110	-3
	20-Aug-96	116	10
38	25-May-95	115	50
	06-Jun-95	140	60
	21-Jun-95	143	63
	22-Jun-95	136	62
	01-Oct-95	150	68
	28-Oct-95	115	43
	24-Apr-96	125	55
	26-Apr-96	141	28
	12-May-96	158	36
	13-May-96	158	53
	12-Jun-96	161	40
	22-Jun-96	158	43

Uma ID	Date	X	Y
39	25-May-95	120	0
	21-Jun-95	120	70
	25-Jul-95	113	82
	31-May-96	113	10
	12-Jun-96	81	-4
	08-Aug-96	90	7
41	25-May-95	97	94
	07-Jun-95	85	85
	21-Jun-95	80	77
	25-Jul-95	70	77
	01-Jun-96	100	92
	11-Jun-96	100	91
	12-Jun-96	101	90
	13-Jun-96	102	102
	13-Jun-96	73	87
	21-Aug-96	113	74
43	25-May-95	160	18
	06-Jun-95	156	14
	22-Jun-95	157	20
46	07-Jun-95	25	109
	13-May-96	48	109
	23-Jun-96	45	93
	21-Aug-96	36	100
	22-Aug-96	42	110
51	25-Jul-95	140	36
	01-Oct-95	178	50
	13-Apr-96	193	22
61	29-Mar-96	118	-4
	26-Apr-96	110	2
	11-May-96	115	-7
	12-May-96	119	4
	16-May-96	116	6
	31-May-96	117	9
	22-Jun-96	118	2
	23-Jun-96	121	4
	24-Jun-96	115	0
	06-Aug-96	136	8
62	29-Mar-96	82	18
	12-Apr-96	45	25
	24-Apr-96	66	14
	27-Apr-96	82	19
	11-May-96	66	14
	12-May-96	56	7
	12-May-96	48	29
	13-May-96	47	27
	31-May-96	42	21
	11-Jun-96	42	20
	12-Jun-96	64	14
	14-Jun-96	38	13
	23-Jun-96	47	10

Uma ID	Date	X	Y
63	29-Mar-96	54	30
	25-Apr-96	50	34
	11-May-96	66	42
	10-Jun-96	65	40
	21-Jun-96	63	55
	21-Jun-96	60	49
66	12-Apr-96	107	7
	24-Apr-96	102	10
	13-May-96	113	7
	01-Jun-96	111	10
	22-Jun-96	118	7
	23-Jun-96	113	10
	08-Aug-96	115	10
	20-Aug-96	112	8
67	24-Apr-96	3	90
	27-Apr-96	10	88
	03-May-96	-5	95
	12-May-96	2	92
68	24-Apr-96	98	90
	14-May-96	94	80
	31-May-96	99	80
	21-Jun-96	97	82
	23-Jun-96	93	80
	21-Aug-96	100	80
71	27-Apr-96	101	103
	14-May-96	123	73
	01-Jun-96	107	88
	11-Jun-96	110	94
	11-Jun-96	104	94
	21-Jun-96	108	82
	21-Jun-96	110	83
	23-Jun-96	126	83
	24-Jun-96	100	107
	06-Aug-96	130	88
	20-Aug-96	129	82
	22-Aug-96	112	94
72	11-May-96	128	77
	01-Jun-96	124	71
	13-Jun-96	121	70
	06-Aug-96	122	82
	20-Aug-96	129	84
	21-Aug-96	123	70
82	06-Aug-96	73	22
	22-Aug-96	74	36

Appendix 3. Individual home range sizes, with minimum convex polygon areas (MCP) and with adjustments of MCPs to correct for sample size bias.

ID#	sex	1995 SVL	1995 HR	N	95 adjusted	1996 SVL	1996 HR	N	96 adjusted
10	F	73	655	3	6154.0	76	220	9	345.8
11	M	70	383	5	1146.2	76	1593	13	1849.3
14	F	58	0	2	0.0	66	0	1	0.0
24	F	73	8	3	75.2	72	0	2	0.0
26	F	57	241	6	569.4	69	396	10	563.3
31	M	63	63	4	276.7		0	0	0.0
32	F	62	80	3	751.6	62	373.5	7	769.9
33	F	75	11	3	103.3		0	1	0.0
34	F	60	0	2	0.0	61	133	7	274.1
38	M	71	158.5	6	374.5	80	599.5	6	1416.4
39	F	75	245	3	2301.9	75	113	3	1061.7
41	F	79	85	4	373.3	80	488.5	6	1154.1
43	F	62	10	3	94.0		0	0	0.0
46	F	63	0	1	0.0	66	115.5	4	507.2
51	M	91	0	2	0.0		0	1	0.0
61	F					45	202	10	287.4
62	M					42	529	13	614.1
63	M					44	170	6	401.6
66	M					42	36	8	63.0
67	F					48	11.5	4	50.5
68	M					50	35	6	82.7
71	M					92	460	12	571.8
72	F					51	70	6	165.4
82	F					46	0	2	0.0
		n sightings	correction						
		3	0.10643564						
		4	0.22772277						
		5	0.33415842						
		6	0.42326733						
		7	0.48514851						
		8	0.57178218						
		9	0.63613861						
		10	0.7029703						
		11	0.7450495						
		12	0.80445545						
		13	0.86138614						
		14	0.89851485						
		15	0.96534653						
		16	1						
		17	1						

Appendix 4. Taxonomic list of arthropods and plants identified from lizard stomach contents, Mohawk Dunes, Yuma Co., Arizona, 1994-1996. Total sample 158 lizards. Numbers indicate number of lizards containing each taxon, not including those identified to lower taxonomic levels.

ARACHNIDA	1
Acarina (Mites, ticks)	12
Araneae (Spiders)	38
Lycosidae (Wolf spiders)	1
Salticidae (Jumping spiders)	10
Pholcidae (Pholcid spiders)	1
Xytiscidae (Crab spiders)	1
Opiliones (Harvestmen)	3
Phalangidae (Daddy long-legs)	2
Scorpiones (Scorpions)	
Vaejovidae	
Paruroctonus	2
Paruroctonus baergi	2
Paruroctonus mesaensis	1
INSECTA	
Apterygota	
Thysanura (Silverfish)	1
Pterygota	
Blattodea (Cockroaches)	
Polyphagidae	
Arenivaga (Desert roaches)	37
Coleoptera (Beetles) (larvae 27 + adults 9)	36
Anobiidae	
Niptus	4
Bruchidae	
Stator limbatus	1
Buprestidae (Metallic wood-boring beetles)	5
Agrilus	2
Chrysobothris	1
Cerambycidae	
Plionoma	1
Coccinellidae	
Hippodamia convergens	7
Hyperapsidius	2
Curculionidae (Snout beetles)	3
Scarabaeidae (Scarab beetles)	4
Acoma nr. *glabrata*	7
Ataenius	1
Diplotaxis	3
Pseudocotalpa	2
Staphylinidae (Rove beetles)	1

Tenebrionidae (Darkling Beetles) (larvae 3, adult 1)	4
Batulius setosus	1
Cheirodes californica	27
Chilometopon	9
Edrotes	5
Eleodes	1
Eusophulus castaneus	1
Notibius puberulus	5
Triorophus ?histrio	1
Diptera (Flies)	22
Asilidae (Robber fly)	3
Hemiptera (Bugs)	1
Homoptera (Leafhoppers, planthoppers, Aphids, Cicadas)	1
Aphididae (Aphids)	9
Macrosiphon	2
Cicadellidae (Leafhoppers)	6
Membracidae (Treehoppers)	1
Multareis	1
Centrodontus	1
?Tingidae (Lace bugs)	1
Heteroptera (True Bugs)	
Cydnidae (Burrower bugs)	3
Microporus	1
Lygaeidae (Seed bugs)	3
Blissus	13
Geocoris	1
Lygaeus rubricollis	1
Nysius raphanus	5
Miridae (Leaf or Plant bugs)	1
Lygus	1
Pentatomidae (Stink bugs)	1
Hymenoptera (Ants, Bees, Wasps)	16
Anthophoridae (Bees)	
Diadasia	1
Formicidae (ants)	2
Aphaenogaster	1
Myrmecocystus kennedyi (Honeypot ants)	32
Pogonomyrmex (Harvester ants)	141
Solenopsis (Fire ants)	23
Veromessor pergandei	102
Dolichoderine	44
Mutillidae (Mutillid wasps)	3
Tiphiidae (Tiphiid wasps)	
?Aglyptacros	1
Brachycistis	1
?Glyptometopa	2
Quemaya	1

Isoptera (Termites)   3
Lepidoptera (Butterflies, Moths) (larvae 8, adult 8)   15
Mantodea (Mantids)
      Mantidae   4
        Litaneutria minor   1
Neuroptera (Antlions, Owlflies, Lacewings)
      Myrmeleontidae (Antlions)   13
        Paranthaclisis   1
Orthoptera (Grasshoppers, Katydids)
      Acrididae (Short-horned grasshoppers)   15
        Paropomala ?pallida   4
        ?Xeracris   1
      Gryllacrididae
        Ceuthophilus   1
        Macrobaenetes   4

ANGIOSPERMA
  Dicotyledoneae   31
      Asteraceae
        Ambrosia dumosa (leaves)   4
        Chaenactis stevioides (seed)   1
        Dicorea canescens (seed)   3
        Geraea canescens (leaves)   1
        Palafoxia arida (seed 5, leaves 2)   7
        Pectis papposa (seed)   12
      Boraginaceae
        Tiquilia plicata (seed 1, leaves 18) 19
      Brassicaceae
        Dithyrea californica (seed)   1
      Fabaceae
        Lupinus arizonicus (seed)   69
        Psorothamnus emoryi (seed 31, leaves 4) 35
      Loasaceae
        Mentzelia multiflora (seed)   2
      Nyctaginaceae
        Abronia villosa (leaves and flowers) 2
  Monocotyledoneae
      Poaceae   5
        Pleuraphis (Hilaria) rigida (seed)   1

Appendix 5. Arthropods and plants identified from lizard stomach contents, Yuma Dunes, Yuma Co., Arizona. Lizards (n=4) collected 3 June 1996. Numbers indicate number of lizards containing each taxon, not including those identified to lower taxonomic levels. Asterisks (*) indicate taxa not found in Mohawk Dunes specimens.

INSECTA
Pterygota
    Coleoptera (Beetles)
        Buprestidae   1
        Dascillidae
           Anorus parvicollis *   1
        Lathridiidae
           Melanophthalma *   1
    Hemiptera (Bugs)
        Heteroptera (True Bugs)
           Lygaeidae
              Nysius raphanus   1
        Homoptera
           Coccidae *   1
    Hymenoptera (Ants, Bees, Wasps)   1
        Formicidae
           Veromessor pergandei   1
           Dolichoderine   1
    Lepidoptera (Butterflies, Moths)   1
    Neuroptera (Antlions, Owlflies, Lacewings)
        Myrmeleontidae   1
    Psocoptera (Booklice, Barklice) *   1

ANGIOSPERMA
    Dicotyledoneae
        Polygonaceae
           Eriogonum deserticola (leaves) *   3

Appendix 6. Collection data for *Uma notata* specimens. All specimens listed were taken from the Mohawk Dunes, AZ, and have been deposited in the University of Arizona Herpetology Collection. Localities are on file with the Arizona Game and Fish Department Heritage Data Management System. Columns in this table contain the following data:

UAZ#	University of Arizona Herpetology Collection number
DST field #	Dale S. Turner's field catalog number
Coll. Date	collection date
Sex	M(ale), F(emale), or Unk(nown)
SVL	snout-to-vent length, in millimeters
Tail	vent-to-tail-tip length, in millimeters
Broken	whether tail is broken, Y(es) or N(o)
Regen	length of regenerated portion of tail, if any
Mass	mass of entire specimen, before preservation, in grams

UAZ #	DST field#	Coll. Date	Sex	SVL(mm)	Tail	Broken	Regen	Mass (g)
50387	004	24-Aug-94	M	89	100	N	N	N
50388	007	29-Apr-95	F	74	64	N	N	16.5
50389	008	29-Apr-95	M	99	82	Y	29	35.3
50390	009	29-Apr-95	M	95	102	N	N	28.7
50391	010	29-Apr-95	F	71	77	N	N	12.7
50392	011	11-May-95	M	63	38	Y	15	7.1
50393	012	11-May-95	M	94	72	Y	6	33.7
50394	013	11-May-95	F	64	73	N	N	8.8
50395	014	11-May-95	M	69	82	N	N	12.1
50396	015	11-May-95	F	69	70	N	N	11.2
50397	016	11-May-95	M	95	109	N	N	30.9
50398	017	11-May-95	F	62	70	N	N	7.3
50399	018	11-May-95	F	62	72	N	N	7.5
50400	019	12-May-95	F	71	67	Y	15	12.6
50401	020	12-May-95	M	89	86	Y	27	24.3
50402	021	12-May-95	F	72	82	N	N	13.2
50403	022	12-May-95	M	71	65	Y	21	9.6
50404	023	12-May-95	M	94	102	N	N	28.8
50405	024	23-May-95	F	65	68	N	N	9.2
50406	025	23-May-95	M	94	102	N	N	25.3
50407	026	23-May-95	F	64	73	N	N	7.9
50408	027	23-May-95	F	69	77	N	N	13.5
50409	028	23-May-95	M	75	82	N	N	14.4
50410	029	23-May-95	M	75	52	Y	31	11.7
50411	031	19-Jun-95	M	93	95	N	N	24.4
50412	032	19-Jun-95	M	93	79	Y	35	26.9
50413	033	19-Jun-95	M	93	70	N	N	10.2
50414	034	19-Jun-95	F	72	73	Y	15	12.4
50415	035	20-Jun-95	F	81	63	Y	23	13.6
50416	036	20-Jun-95	M	98	96	Y	16	26.5
50417	037	20-Jun-95	F	78	83	N	N	14.9
50418	038	20-Jun-95	M	100	109	Y	15	32.6
50419	039	22-Jun-95	F	83	77	Y	37	15.7
50420	040	22-Jun-95	F	75	80	N	N	13.8
50421	041	22-Jun-95	F	68	78	N	N	9.9
50422	042	22-Jun-95	M	93	111	N	N	26.1
50423	043	22-Jun-95	F	75	74	Y	6	12.8
50424	044	22-Jun-95	F	78	78	N	N	11.0
50425	045	22-Jun-95	M	90	94	Y	21	29.1
50426	046	22-Jun-95	F	69	47	Y	29	11.8
50427	047	30-Apr-95	M	97	107	N	N	28.9
50428	048	30-Apr-95	M	100	111	N	N	34.0
50429	049	30-Apr-95	M	87	37	Y	0	20.5
50430	050	30-Apr-95	M	74	83	N	N	14.9
50431	051	30-Apr-95	F	78	83	Y	6	15.0
50432	052	30-Apr-95	F	67	82	N	N	12.3

50433	053	30-Apr-95	F	68	79	N	N	11.3
50434	054	30-Apr-95	F	69	79	N	N	12.4
50435	055	30-Apr-95	F	73	48	N	N	10.6
50436	056	30-Apr-95	F	66	72	N	N	10.2
50437	057	12-Jul-95	M	79	81	Y	8	13.0
50438	058	12-Jul-95	F	65	47	Y	0	7.3
50439	059	12-Jul-95	M	89	100	N	N	20.6
50440	060	12-Jul-95	F	76	28	Y	56	11.3
50441	061	13-Jul-95	M	85	73	Y	36	18.7
50442	062	13-Jul-95	M	61	70	N	N	6.8
50443	063	13-Jul-95	F	70	46	Y	18	10.2
50444	064	13-Jul-95	F	65	76	N	N	9.8
50445	065	13-Jul-95	M	97	82	Y	34	27.4
50446	066	13-Jul-95	M	84	78	Y	39	18.1
50447	067	13-Jul-95	M	93	91	Y	15	23.0
50448	068	13-Jul-95	F	74	81	N	N	9.3
50449	069	24-Jul-95	M	40	48	N	N	1.9
50450	072	25-Jul-95	F	38	26	Y	0	1.5
50451	077	26-Jul-95	F	63	77	N	N	7.4
50452	078	26-Jul-95	M	98	89	Y	0	26.2
50453	079	26-Jul-95	F	53	53	Y	22	6.0
50454	080	27-Jul-95	F	78	57	Y	23	11.4
50455	081	27-Jul-95	F	77	64	Y	35	11.2
50456	083	31-Aug-95	M	35	50	N	N	2.0
50457	084	31-Aug-95	F	41	52	N	N	2.2
50458	085	31-Aug-95	F	36	44	N	N	1.5
50459	086	1-Sep-95	M	90	74	Y	38	20.1
50460	087	1-Sep-95	M	82	38	Y	0	14.5
50461	088	1-Sep-95	M	97	84	Y	53	22.0
50462	090	28-Sep-95	F	50	63	N	N	3.4
50463	091	2-Oct-95	F	67	69	Y	6	6.3
50464	092	2-Oct-95	M	71	83	N	N	10.1
50465	094	27-Mar-96	M	52	60	N	N	3.5
50466	095	27-Mar-96	Unk	45	40	Y	0	2.7
50467	096	27-Mar-96	M	44	43	Y	6	2.6
50468	097	27-Mar-96	F	53	61	N	N	4.4
50469	098	27-Mar-96	F	51	42	Y	18	N
50470	099	27-Mar-96	F	77	75	Y	7	12.3
50471	100	13-Apr-96	M	87	94	N	N	16.5
50472	101	14-Apr-96	M	51	61	N	N	3.8
50473	106	24-Apr-96	M	93	50	Y	0	19.5
50474	107	24-Apr-96	F	Unk	67	N	N	4.6
50475	108	24-Apr-96	F	69	67	Y	0	9.2
50476	109	25-Apr-96	M	87	88	Y	17	18.5
50477	110	25-Apr-96	F	67	20	Y	0	7.4
50478	111	25-Apr-96	M	93	69	Y	44	21.5
50479	113	26-Apr-96	M	87	84	Y	0	17.8

50480	114	26-Apr-96	F	79	52	Y	20	11.1
50481	115	27-Apr-96	M	91	100	Y	0	20.5
50482	116	27-Apr-96	F	73	62	Y	29	12.0
50483	117	27-Apr-96	F	48	63	N	N	3.5
50484	118	27-Apr-96	M	59	72	N	N	5.5
50485	119	2-May-96	F	65	80	N	N	7.4
50486	120	2-May-96	M	92	109	N	N	25.2
50487	121	2-May-96	F	47	56	Y	0	2.9
50488	122	2-May-96	F	52	58	N	N	3.9
50489	123	2-May-96	F	44	50	Y	0	2.6
50490	124	2-May-96	F	72	63	Y	35	11.3
50491	125	2-May-96	F	51	60	N	N	3.6
50492	126	2-May-96	M	100	108	Y	19	25.1
50493	127	2-May-96	F	48	33	Y	0	2.7
50494	128	3-May-96	M	92	110	N	N	21.2
50495	129	3-May-96	M	102	79	Y	34	26.7
50496	130	4-May-96	M	98	99	Y	14	25.4
50497	131	4-May-96	M	48	58	N	N	3.3
50498	132	4-May-96	F	44	40	Y	8	2.2
50499	133	15-May-96	F	63	73	N	N	7.9
50500	134	15-May-96	M	52	62	N	N	3.9
50501	135	15-May-96	M	96	54	Y	23	22.8
50502	136	15-May-96	F	71	81	N	N	10.6
50503	137	15-May-96	M	52	64	N	N	4.1
50504	138	15-May-96	F	76	69	Y	12	10.0
50505	139	3-Jun-96	F	53	60	N	N	4.4
50506	140	3-Jun-96	M	57	57	Y	12	5.0
50507	141	3-Jun-96	M	82	82	Y	11	15.3
50508	142	3-Jun-96	M	74	62	Y	31	11.8
50509	143	10-Jun-96	M	51	36	Y	17	4.2
50510	144	10-Jun-96	M	61	80	N	N	7.2
50511	145	10-Jun-96	F	64	65	Y	18	7.0
50512	146	10-Jun-96	M	54	66	N	N	4.5
50513	147	10-Jun-96	M	89	100	N	N	22.2
50514	148	11-Jun-96	F	47	59	N	N	3.3
50515	149	11-Jun-96	M	93	73	Y	15	19.6
50516	150	12-Jun-96	M	54	66	N	N	4.4
50517	151	12-Jun-96	M	96	96	Y	44	28.9
50518	152	12-Jun-96	M	101	115	N	N	28.8
50519	153	12-Jun-96	M	55	69	N	N	4.6
50520	154	12-Jun-96	F	67	82	N	N	7.9
50521	155	13-Jun-96	F	68	78	N	N	7.9
50522	156	13-Jun-96	F	72	58	Y	20	9.7
50523	157	13-Jun-96	F	48	60	N	N	3.2
50524	158	13-Jun-96	F	48	37	Y	0	3.6
50525	159	14-Jun-96	F	56	66	N	N	4.6
50526	160	14-Jun-96	M	97	81	Y	34	19.1

50527	161	14-Jun-96	F	63	60	Y	8	6.0
50528	162	14-Jun-96	F	72	80	Y	0	10.1
50529	163	16-Jul-96	M	90	91	Y	31	20.0
50530	164	16-Jul-96	F	55	66	N	N	4.8
50531	165	16-Jul-96	F	75	78	Y	22	12.2
50532	166	16-Jul-96	F	56	74	N	N	6.0
50533	167	16-Jul-96	M	59	47	Y	8	5.1
50534	168	16-Jul-96	M	58	67	N	N	5.0
50535	169	17-Jul-96	M	89	99	N	N	20.5
50536	170	17-Jul-96	M	Unk	33	Y	0	5.4
50537	171	17-Jul-96	M	94	29	Y	0	21.5
50538	172	17-Jul-96	F	67	81	N	N	7.9
50539	173	18-Jul-96	M	66	22	Y	0	8.1
50540	174	18-Jul-96	M	98	101	Y	25	21.0
50541	175	18-Jul-96	F	51	63	N	N	4.7
50542	176	18-Jul-96	F	Unk	51	N	N	2.8
50543	177	18-Jul-96	M	91	87	Y	35	19.6
50544	178	6-Aug-96	F	75	70	Y	31	10.3
50545	179	6-Aug-96	M	66	81	N	N	7.9
50546	180	6-Aug-96	F	51	66	N	N	3.6
50547	181	7-Aug-96	F	53	68	N	N	3.9
50548	182	7-Aug-96	M	53	28	Y	12	4.3
50549	183	8-Aug-96	F	45	56	N	N	2.4
50550	184	8-Aug-96	F	58	74	N	N	5.0
50551	185	8-Aug-96	M	86	101	N	N	15.2
50552	186	8-Aug-96	F	55	66	N	N	3.6
50553	187	20-Aug-96	F	67	61	Y	25	7.2
50554	188	20-Aug-96	M	68	61	Y	31	8.8
50555	189	20-Aug-96	M	69	68	Y	9	8.7
50556	190	20-Aug-96	F	68	80	N	N	9.0
50557	191	20-Aug-96	F	68	76	N	N	8.4
50558	192	21-Aug-96	F	66	52	Y	31	9.3
50559	193	21-Aug-96	F	50	62	N	N	3.7

Appendix 7. Statistical values for mass-length regression comparisons. Regressions were calculated on subsets of the combined data set of collected lizards and marked lizards at first capture for each year, using total mass for each lizard as a variable dependent on the cube of its snout-vent length. Comparison t tests were calculated first on slopes of the regression lines, then on elevations if the slopes were not significantly different (Zar 1996).

Regression values

data set	regression equation	N	r^2	F ratio	probability
1995 Females	mass= 1.04784 + 0.0000295 SVL^3	68	0.765	218.86	<0.0001
1995 Males	mass= -0.4111 + 0.0000326 SVL^3	60	0.880	435.43	<0.0001
1996 Females	mass= 0.46675 + 0.0000260 SVL^3	68	0.904	632.72	<0.0001
1996 Males	mass= 0.55234 + 0.0000261 SVL^3	65	0.958	1474.27	<0.0001
1995 M+F	mass= 0.19231 + 0.0000318 SVL^3	128	0.892	1053.72	<0.0001
1996 M+F	mass= 0.4691 + 0.0000262 SVL^3	134	0.960	3204.27	<0.0001
1995 spring M+F	mass= 0.2723 + 0.0000331 SVL^3	88	0.877	623.46	<0.0001
1995 fall M+F	mass= 0.13992 + 0.0000278 SVL^3	40	0.971	1305.57	<0.0001
1996 spring M+F	mass= 0.41013 + 0.0000266 SVL^3	95	0.962	2388.90	<0.0001
1996 fall M+F	mass= 0.55594 + 0.0000251 SVL^3	35	0.972	1172.28	<0.0001

t test values

data sets	property	t statistic	DF	probability (2-tailed)
1995 F vs. M	slope	-0.96805	124	p=0.33
"	elevation	0.6220	125	p=0.53
1996 F vs. M	slope	-0.0664	129	p=0.94
"	elevation	-0.3829	130	p=0.70
1995 vs. 1996, M+F	slope	5.2865	258	p<0.001
spring 95 vs. fall 95, M+F	slope	2.8476	124	p=0.005
spring 96 vs. fall 96, M+F	slope	1.4108	126	p=0.16
"	elevation	1.2589	127	p=0.21
spring 95 vs. spring 96, M+F	slope	4.822	179	p<0.001
fall 95 vs. fall 96, M+F	slope	2.460	71	p=0.016

Appendix 8. Mohawk Dunes lizard transect results, 1994-1996. Crash North and South transects are each 500 m long, and were combined to give *Uma*/km values. Playa crest transect is 1 km long. Values also given for total number of lizards of all species seen, number of *Uma* seen on a transect, time spent walking each transect, and starting temperatures at 1.5 m, 5 mm, and on the surface. Details of routes and methods are provided in Turner et al. (1997a).

Location	Date	#lizards	#Uma	Uma/km	Minutes	T 1.5m (°C)	T 5mm (°C)	T s (°C)
Crash N	15-Jul-94	3	3	5	13	36.4	38.5	43.2
Crash S	15-Jul-94	3	2		13	34.4	36.2	42.2
Crash N	7-Aug-94	2	2	5	10	37.8	39.4	44.2
Crash S	7-Aug-94	3	3		10	36.4	37.6	41.5
Crash N	23-Oct-94	3	1	2	9	30.3	32.6	36.0
Crash S	23-Oct-94	1	1		9	30.2	33.7	36.5
Crash N	23-May-95	5	3	8	10	23.9	26.7	35.1
Crash S	23-May-95	8	5		12	23.0	30.1	38.3
Crash N	20-Jun-95	5	5	6	10	29.6	32.1	36.1
Crash S	20-Jun-95	1	1		8	32.3	35.7	39.2
Crash N	27-Jul-95	3	2	4	11	32.9	33.5	34.4
Crash S	27-Jul-95	3	2		9	34.9	35.6	37.5
Crash N	31-Aug-95	1	1	3	8	33.7	36.1	38.9
Crash S	31-Aug-95	2	2		8	35.7	37.4	41.0
Crash N	29-Oct-95	2	2	6	8	30.0	32.3	36.1
Crash S	29-Oct-95	4	4		9	30.5	31.4	35.5
Crash N	27-Apr-96	2	2	3	9	32.4	35.1	43.4
Crash S	27-Apr-96	1	1		8	33.0	35.2	37.7
Crash N	3-May-96	3	2	3	11	28.3	29.2	33.7
Crash S	3-May-96	1	1		8	30.7	35.6	45.0
Crash N	1-Jun-96	0	0	3	7	29.3	32.3	39.6
Crash S	1-Jun-96	4	3		10	31.4	33.0	41.1
Playa crest	24-Aug-94	4	4	4	21	34.7	35.5	40.4
Playa crest	27-Sep-94	6	5	5	21	32.7	34.1	34.8
Playa crest	22-Oct-94	5	5	5	20	25.4	26.8	30.1
Playa crest	29-Apr-95	6	3	3	19	26.1	29.3	36.5
Playa crest	24-May-95	6	6	6	19	23.8	26.3	32.9
Playa crest	21-Jun-95	3	3	3	17	30.4	33.0	41.3
Playa crest	26-Jul-95	3	3	3	19	32.0	32.1	32.7
Playa crest	1-Sep-95	2	2	2	17	32.8	32.8	32.9
Playa crest	29-Sep-95	2	2	2	16	23.9	25.3	32.7
Playa crest	28-Oct-95	2	2	2	16	28.0	30.9	37.7
Playa crest	28-Mar-96	3	3	3	18	25	27.6	34.3
Playa crest	25-Apr-96	6	6	6	19	30.4	31.5	36.8
Playa crest	4-May-96	3	1	1	17	30.6	34.3	39.6
Playa crest	11-May-96	1	1	1	15	31.4	33.7	39.2
Playa crest	31-May-96	1	1	1	16	30.1	32.5	41.9